DOCUMENT RESUME

ED 173 645 CE 022 314

AUTHOR	Ross-Harrington, Melinda; Kincaid, G. David
TITLE	Water Treatment Technology - Chlorination.
INSTITUTION	West Virginia Research Coordinating Unit for Vocational Education, Huntington.; West Virginia State Dept. of Education, Charleston. Bureau of Vocational, Technical, and Adult Education.; West Virginia State Dept. of Health, Charleston.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	Dec 78
GRANT	G007603801; H007800069
NOTE	132p.; For related documents see CE 022 313-324 ; Not available in hard copy due to marginal legibility
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Adult Education; Educational Objectives; Evaluation Methods; Individualized Curriculum; Instructional Materials; *Job Skills; Learning Activities; Public Health; Trade and Industrial Education; *Utilities; Water Resources
IDENTIFIERS	*Chlorination; *Water Treatment; West Virginia

ABSTRACT

One of twelve water treatment technology units, this student manual on chlorination provides instructional materials for nine competencies. (The twelve units are designed for a continuing education training course for public water supply operators.) The competencies focus on the following areas: purpose and process of chlorination, chlorine residuals, free chlorine determination, raw water chlorine demand test, gas chlorinators construction, gas chlorinator use and safety precautions, first aid for chlorine gas victims, hypochlorite solution preparation, and using a hypochlorinator. For each competency, student objective, resources (information sheets, references to manuals, and appendix materials), learning activities, and evaluation activities are provided. The appendices contain information sheets on chlorination. Generally, an evaluation form with answer key is provided for each student competency. (JH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

AUG 2 1 RECD

ED173645

Water Treatment Technology

CHLORINATION

Developed by
Melinda Ross-Harrington
Field Tested and Revised by
G. David Kincaid
Research Coordinating Unit
for Vocational Education
Marshall University
Huntington, West Virginia

December, 1978

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

Developed through the West Virginia Bureau of Vocational, Technical, and Adult Education, the West Virginia Research Coordinating Unit for Vocational Education, and the West Virginia Department of Health pursuant to a grant from the U. S. Office of Education. The opinions expressed herein do not necessarily reflect the position or policy of the U. S. Office of Education and no official endorsement by the U. S. Office of Education should be inferred.

U.S.O.E. Original Grant No. G007603801 &
U.S.O.E. Field Test Grant No. H007800069

CE 022 314

CHLORINATION

EVALUATOR'S COPY

Table Of Contents

Item	Page
Acknowledgements	1
Evaluator's Instructions	1A
Instructions For The Student Operator	2
Explanation of Continuing Education Units	4
Purpose and Process of Chlorination	5
Chlorine Residuals--Total, Free, and Combined	7
Free Chlorine Determination	8
Raw Water Chlorine Demand Test	9
Gas Chlorinators-Construction	12
Gas Chlorinator Use and Safety Precautions	13
First Aid For Chlorine Gas Victims	25
Hypochlorite Solution Preparation	27
Using A Hypochlorinator	37

Appendices

Chlorination - Blue Appendix	41
Chlorination of Smaller Water Supplies - Gold Appendix	59
Chlorination Equipment-Operation and Maintenance Yellow Appendix	66
Disinfection of Water (Chlorination) - Pink Appendix	77
The Chlorination of Water - Buff Appendix	89
Chlorinators (Location, Operation, and Maintenance) Green Appendix	108
Laboratory Equipment and Supply Requirements For A Small Water Treatment Plant Providing Complete Treatment - Salmon Appendix	117

ACKNOWLEDGEMENTS

Project Co-Directors

Col. T. A. Welty
Coordinator of Public Service Occupations Education
Bureau of Vocational, Technical, and Adult Education
West Virginia State Department of Education
Charleston, West Virginia

Donald Kuntz, P.E.
Chief, Drinking Water Program
Environmental Health Services
West Virginia Department of Health
Charleston, West Virginia

David Ball, P.E.
Engineer, Drinking Water Program
Environmental Health Services
West Virginia Department of Health
Charleston, West Virginia

Graphics

Robert Lilly
Vocational Curriculum Laboratory
West Virginia Bureau of Vocational, Technical, and
Adult Education
Cedar Lakes Conference Center
Ripley, West Virginia

Typing/Editing

Joann Turner and Kristine Standifur
Research Coordinating Unit for Vocational Education
Marshall University
Huntington, West Virginia

EVALUATOR'S INSTRUCTIONS

Name _____

Address _____

_____

Phone _____

This is your EVALUATOR'S COPY of the CHLORINATION unit. It contains all of the materials received by the operators who will be working on the unit. It also contains *answer keys* and *directions* for the evaluation of each Competency. For each Competency Sheet, there is a COMPETENCY, a list of RESOURCES, LEARNING ACTIVITIES, and EVALUATION ACTIVITIES.

Your student operators will call you when they are ready to be evaluated. An operator may complete the evaluations in *any* order. S/he may choose to complete one at a time, or several at one time. *It is up to you and each operator to set convenient schedules for the evaluations.* It is important that the operators learn the skills listed in each competency. It is <u>your</u> job to be sure the operators can perform the competencies.

If an operator does <u>not</u> complete an evaluation correctly, s/he may try again later after practicing the skills. It would be helpful for you to tell the operators just how they should improve their knowledge and skills in order to complete the evaluation successfully. Be sure to call if you have any questions.

This package contains:

----- Chlorination Unit
----- Evaluation Forms for each Competency

You will receive instructions as to where to send the completed evaluation forms. Please be sure that the operator's name and your name are on the forms, as well as the date on which the evaluation was performed.

INSTRUCTIONS FOR THE STUDENT OPERATOR

The CHLORINATION unit contains nine competencies. A "competency" is a skill that is necessary for good on-the-job performance. Each competency in this unit is necessary for you to perform on the job according to the West Virginia Department of Health. There is a Competency Sheet to help you understand each competency.

DIRECTIONS FOR COMPLETING THE UNIT:

1. Read each Competency Sheet carefully. Every Competency Sheet contains:

   COMPETENCY
   Objectives
   RESOURCES
   LEARNING ACTIVITIES
   EVALUATION ACTIVITY(IES)

2. After reading the whole Competency Sheet, you should understand what will be expected of you.

3. Do the LEARNING ACTIVITIES that you think will help you the most. This may include reading some of the RESOURCES which have been included with the unit.

4. If you need additional help, ask an operator in your plant for assistance, or call your evaluator; he's there to help you.

5. When you are ready to complete the EVALUATION ACTIVITY for one or more competencies--call your evaluator. The two of you will schedule the best time for your evalution.

   a. If you complete the evaluation correctly, go on to the next competency.
   b. If you do <u>not</u> complete the evaluation correctly, your evaluator will tell you what your mistakes were. You must go back and practice your skills and read the RESOURCES again. Call your evaluator when you are ready to try again. *You must wait at least one week before being re-evaluated on a competency.*

SEE NEXT PAGE

6. When you complete all your evaluations correctly you will receive a Certificate of Accomplishment and 2.5 Continuing Education Units of Credit.

7. If you want to go on to another unit, contact your evaluator for the materials. The procedure will be similar for all units.

AN EXPLANATION OF CONTINUING EDUCATION UNITS

For student operators in the OPERATOR-IN-TRAINING category who will be taking the certification examination for Class I, this course is an opportunity to increase your knowledge and competence in the treatment of water for human consumption. Successful completion of the manuals will also, it is hoped, make passing the certification exam much easier. The Continuing Education Units which you will get by taking this course will not decrease the minimum one year operating experience requirement for a Class I certificate.

For student operators who now hold a Class I certificate, the completion of all twelve manuals in the course will reduce the currently required three years of total operating experience for Class II certification by approximately four months. Thus, if you complete the course, you will need only two years and eight months of total operating experience before you take the Class II exam.

Here is a listing of the Continuing Education Unit (CEU) value of each of the manuals.

Manual	CEU Value
General Plant Operation	1.4
Taste, Odor, and Color	0.6
Chemistry/Bacteriology	2.5
Chlorination	2.5
Fluoridation	0.6
Filtration	1.2
Hydraulics	0.6
Distribution Systems	1.2
Pumps	0.6
Wells	1.0
Cross Connections	0.4
Springs	0.4
Total	13.0

For comparison with other types of training previously available, the CEU conversions below are given.

Public Water Supply Operator's Short Course (given by State Department of Health Personnel)	4 CEUs
One Semester Hour of College Credit	1.5 CEUs
One Year of College Credits (30 semester hours)	45 CEUs

COMPETENCY: Describe the purpose and process of chlorination.

Objective: Describe what changes occur in raw water when chlorine is added.

Objective: Describe the various ways in which chlorine may be added to water.

Objective: Explain how time and temperature and pH effect changes in the way chlorine reacts with water.

Objective: Describe how six different substances, if present in the raw water, may effect the process of chlorination.

RESOURCES:

(a) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, New York 12224. *-Blue Appendix-*

(b) "Chlorination of Smaller Water Supplies", by James E. Rosencrance, Chief Chemist, Division of Sanitary Engineering, W. Va. State Department of Health. *-Gold Appendix-*

(c) BASIC WATER TREATMENT OPERATOR'S MANUAL, No. M 18, American Water Works Association, 2 Park Avenue, New York, N. Y. 10016, 1971. *-Yellow Appendix-*

(d) Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XVII. *-Pink Appendix-*

(e) "The Chlorination of Water," West Virginia State Department of Health. *-Buff Appendix-*

LEARNING ACTIVITIES:

(a) Read the recommended resources to find background information relating to the objectives.

(b) Attend a lecture/demonstration on the process of chlorination.

(c) Observe a trained operator adding chlorine to raw water at his/her treatment plant.

EVALUATION ACTIVITY:

Complete Evaluation Form #23. You will be expected to complete the form correctly using no references. It contains questions relating to:

(a) the changes that occur in raw water when chlorine is added,

(b) the various ways in which chlorine may be added to water,

(c) the ways in which time, temperature, and pH levels affect chlorination, and

(d) six different substances that may affect the process of chlorination.

Operator _____

Evaluator _____

Date _____

This evaluation may be completed orally or in writing.

Directions: In the space provided, write the word "True" or "False" next to each item. If you answer "False" write the correct answer on the line(s) under the question.

1. *True* Chlorine remains in cold water longer than it does in warm water.

2. *True* Chlorine may be added to water as a gas or as a solution.

3. *False* Suspended solids will not affect chlorination.
They may shield bacteria from the destructive action of chlorine.

4. *False* Ammonia reacts with free chlorine, but does not affect disinfection.
Ammonia reacts with free chlorine to form a chlorine compound having less disinfecting qualities than free chlorine itself.

5. *True* Organic matter may react with chlorine and "use up" its ability to disinfect water.

6. False — The minimum time that chlorine should be in contact with water in order to be effective is three minutes.
Minimum time required is 30 minutes before it reaches the first customer according to W.Va. Public Water Supply Regulations.

7. False — Chlorine should not be added to water that has any chemicals in it.
Chlorine may be added in conjunction with other chemicals or before or after other chemicals are added to the water.

8. False — Waters with high pH values are the easiest to disinfect.
High pH water is difficult to disinfect. Low pH waters are much easier to disinfect.

9. True — Chlorine may be used to kill disease organisms.

10. True — Chlorine may be used to remove iron and manganese from water.

11. True — Chlorination is most effective with high water temperatures.

12. True — Chlorine may be used to kill some kinds of algae and slime growth.

COMPETENCY: Describe each of the following:
(a) total chlorine residual
(b) free chlorine residual
(c) combined chlorine residual

Objective: Describe the differences between "total", "free", and "combined" chlorine residual.

Objective: Describe the advantages of free chlorine residual.

RESOURCES:

(a) BASIC WATER TREATMENT OPERATOR'S MANUAL, No. M 18, American Water Works Association, 2 Park Avenue, New York, N. Y. 10016, 1971. pp. 37-43. *-Yellow Appendix-*

(b) "Chlorination of Smaller Water Supplies", by James E. Rosencrance, Sanitary Chemist, Division of Sanitary Engineering, W. Va. State Department of Health. *-Gold Appendix-*

(c) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, New York 12224. *-Blue Appendix-*

(d) Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XVII, pp. 7-8. *-Pink Appendix-*

LEARNING ACTIVITIES:

(a) Read the recommended resources for background information relating to the objectives.

(b) Attend a lecture/demonstration on the process of chlorination.

EVALUATION ACTIVITY: Complete Evaluation Form # 24. You will be expected to complete the form correctly using no references. It contains questions relating to:

(a) the definitions of total chlorine residual, free chlorine residual, and combined chlorine residual,

(b) the differences between "total", "free", and "combined" chlorine residuals, and

(c) the advantages of free chlorine residual.

(Chlorination #24)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

Directions: In the space provided write the word "True" or "False" next to each item. If you answer "False" write the correct answer on the line(s) under the question.

1. *True* Combined chlorine residual requires a much longer contact period for disinfection than does free chlorine residual.

2. *True* "Total chlorine residual" is the total of free available residual chlorine and combined available residual chlorine.

3. *False* Combined chlorine will react with manganese and organic matter.
Free chlorine will react with manganese or organic matter but combined chlorine will not.

4. *True* Free chlorine sometimes causes water to smell bad.
NOTE: Although free chlorine will sometimes eliminate tastes and odors, at other times odors may be intensified.

5. *False* Combined chlorine will not last as long in the distribution system as free chlorine.
Because combined chlorine does not react with the slimes found in water mains, it will persist much further out into the distribution system than will free chlorine.

6. *True* Combined chlorine is "milder" than free chlorine and requires higher concentrations over longer periods of time.

COMPETENCY: Demonstrate the ability to determine the amount of free chlorine present in water.

Objective: Describe the reason for determining the amount of free chlorine present in water.

Objective: Demonstrate your ability to use the DPD method to determine the amount of free chlorine present in water.

RESOURCES:

(a) DPD Free and Total Chlorine Test kit.

(b) "Chlorination of Smaller Water Supplies," by James E. Rosencrance, Sanitary Chemist, Division of Sanitary Engineering, W.Va. State Department of Health. *-Gold Appendix-*

(c) "The Chlorination of Water," West Virginia State Department of Health. *-Buff Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about testing for free chlorine.

(b) Using a DPD chlorine test kit, determine the amount of free chlorine present in your treated water. Practice using the kit by performing the same test in the morning and the evening for several days. Be sure to follow the manuafacturer's instructions included with the test kit.

EVALUATION ACTIVITY: Using the DPD method, demonstrate your ability to determine the amount of free chlorine present in your finished water. Follow the test kit manufacturer's directions carefully. Explain to your evaluator how you will use the information obtained from the test.

COMPETENCY: Determine the chlorine demand for raw water entering your treatment plant.

Objective: Define chlorine demand and explain why it is important to water treatment.

Objective: Perform the test for measuring chlorine demand.

RESOURCES:

(a) "Estimating Chlorine Dosage" Resource Sheet, provided with module.

(b) SIMPLIFIED PROCEDURES FOR WATER EXAMINATION-Laboratory Manual, No. M 12, American Water Works Assoc., 6666 W. Quincy Avenue, Denver, Colorado 80235, 1975. pp. 46-49.

(c) Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XVII. *-Pink Appendix-*

(d) Water Chemistry Laboratory Manual, by James E. Rosencrance, Division of Sanitary Engineering, W. Va. State Health Dept., 1964. p. 28.

(e) Laboratory equipment and supply requirements for a small water treatment plant providing complete treatment *-Salmon Appendix-*

(f)
1. Five or more clean quart-size bottles or flasks.
2. A dropping pipet or medicine dropper for dispensing the chlorine dosing solution. Use a pipet or dropper that delivers 1.0 ml water in 20 drops.
3. A 500 ml graduated cylinder for measuring the sample.

AND

(Used for Titrimetric Method)
4. 10-ml buret and support
5. 100-ml graduated cylinder or appropriate volumetric pipets for measuring the sample
6. One or more 250-ml flasks
7. Two 5-ml automatic, safety, or bulb operated pipets for dispensing DPD reagent and phosphate buffer solution

(Used for Colorimetric Method)
4. 100-ml graduated cylinder or appropriate volumetric pipets for measuring the sample
5. Two 5-ml automatic, safety, or bulb operated pipets for dispensing DPD reagent and phosphate buffer solution
6. Nessler tubes, 100 ml, tall form or low form, and support

7. A 10-ml buret or appropriate pipets for measuring dilute potassium permanganate solution
8. Clean rubber stoppers (No. 3 or larger size) for nessler tubes
9. 250-ml beakers
10. Comparator with permanent color standards in the appropriate chlorine range from 0.0 to 1.0 mg/l; 0.0 to 2.0 mg/l; or greater chlorine range

LEARNING ACTIVITIES:

(a) Read the recommended resources for information and instructions on how to perform a chlorine demand test.

(b) Attend a demonstration on how to perform a chlorine demand test.

(c) Under supervision of the instructor, perform a chlorine demand test until you are confident you can perform it correctly by yourself.

EVALUATION ACTIVITY:

Notify your instructor that you are ready to be evaluated on the chlorine demand test. You may use references while you are evaluated.

(a) Briefly describe to your instructor what "chlorine demand" means and why it is important to water treatment.

(b) Using all necessary equipment properly, perform a chlorine demand test. Record the chlorine dosage added, the free available residual chlorine found, the contact time, and the temperature at which each sample was kept during the contact period. CALCULATE THE CHLORINE DEMAND.

ESTIMATING CHLORINE DOSAGE*

Estimating Dosage. To estimate dosage where no prior record of chlorination exists, or where chlorine demand changes frequently:

(1) Determine chlorine demand in accordance with procedure given in laboratory tests, or start chlorine feed at a low rate and raise feed by small steps; at the same time make repeated residual tests until a trace is found. Observe rate of flow treated and rate of chlorine feed at this point. Chlorine demand then equals dosage and is determined from the following equation:

$$\text{Dosage in ppm} = \frac{\text{Rate of feed in pounds per day}}{8.34 \times \text{flow in mgd}}$$

(2) Add the minimum ppm required residual to the ppm demand in order to estimate the ppm dosage required to obtain a satisfactory residual. Then set chlorinator rate of feed in accordance with the above estimated ppm dosage. Further upward adjustment after making residual tests are usually required because the demand increases as the residual is increased.

Checking Rate of Feed:

(1) To ascertain that chlorinator is feeding the indicated amount, the cylinders are usually mounted on a platform scale. Loss in weight during the check period is observed.

$$\text{Rate of Feed} = \frac{\text{Loss in weight} \times 24}{\text{Check period in hours}} = \text{pounds per day.}$$

Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, Reprint dated June 15, 1968. pp. 115-116.

COMPETENCY: Sketch, label, and describe the operation of the chlorinator(s) in your treatment plant.

Objective: Closely examine the construction of the chlorinator(s) in your plant.

Objective: Become familiar with the operator's manual provided with your chlorinator(s).

RESOURCES:

(a) Gas chlorinator

(b) Operator's manual for chlorinator

(c) BASIC WATER TREATMENT OPERATOR'S MANUAL, No. M 18, American Water Works Association, 1971. pp. 54-56. *-Yellow Appendix-*

(d) "The Chlorination of Water", West Virginia State Department of Health. *-Buff Appendix-*

LEARNING ACTIVITIES:

(a) Closely examine the gas chlorinator(s) in your treatment plant. Use the operator's manual for reference. Read additional resources if necessary.

(b) Attend a lecture/demonstration on the operation of gas chlorinators.

(c) Test yourself on your ability to identify the parts of your gas chlorinator by sketching and labeling all basic parts of the chlorinator. Check your accuracy with the operator's manual.

EVALUATION ACTIVITY: Notify your instructor when you are ready to sketch and label your gas chlorinator using no references. Your sketch must include the following:

(a) chlorine cylinder

(b) main tank valve

(c) auxiliary tank valve

(d) tank pressure gauge

(e) back pressure gauge

(f) back pressure valve

COMPETENCY: Demonstrate the use of a gas chlorinator employing all appropriate safety precautions.

Objective: Describe an appropriate location for a gas chlorinator.

Objective: Demonstrate the proper procedure for performing a routine maintenance check on a gas chlorinator.

Objective: Demonstrate the ability to clean interior and exterior parts and perform minor repairs on a gas chlorinator.

Objective: Describe the relationship between temperature and pressure for a gas chlorinator.

RESOURCES:

(a) Gas chlorinator

(b) "A Revue of Chlorine Accidents", (Excerpts from article appearing in Journal of American Water Works Association, Volume 30, Number 10.) Resource Sheet I, provided with module.

(c) GAS CHLORINATORS - MAINTENANCE AND REPAIR, Resource Sheet III, provided with module.

(d) PRECAUTIONS IN CHLORINATION OPERATION, Resource Sheet II , provided with module.

(e) Manufacturer's instruction booklet (operator's manual) provided with gas chlorinator.

(f) "The Chlorination of Water", West Virginia State Department of Health. *-Buff Appendix-*

(g) "Chlorination of Smaller Water Supplies", by James E. Rosencrance, Sanitary Chemist, Division of Sanitary Engineering, W. Va. State Department of Health. *-Gold Appendix-*

(h) Water Works Operators Manual, Third Edition, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama, Chapter XVIII Adapted from a lecture given by James W. Fly, Wallace and Tiernan Representative. *-Green Appendix-*

LEARNING ACTIVITIES:

(a) Read the recommended resources to find background information relating to the objectives.

(b) Study the drawings of a gas chlorinator.

(c) Under supervision of the instructor, practice the steps involved in performing a routine maintenance check on a gas chlorinator.

(d) Under supervision of the instructor, clean the internal and external parts of a gas chlorinator including the rotameter, chlorine pressure reducing valve and the springs.

(e) Under supervision of the instructor, perform the tasks necessary to detect and stop a leak on a gas chlorinator.

(f) Practice keeping a record of each maintenance check and repair done on a gas chlorinator. Include date, status of parts, parts cleaned (if any), and parts repaired (if any).

EVALUATION ACTIVITIES:

After correctly completing Evaluation Form #28, Part I, using no references, notify your instructor that you are ready to demonstrate your ability to operate and maintain a gas chlorinator. In addition to the Evaluation Form #28, Part I, you will be evaluated on the following criteria:

Maintenance check, cleaning, and minor repairs

(a) Demonstrate the proper use of all necessary protective equipment and clothing.

(b) Make sure that chlorinator is feeding correct amount of chlorine.

(c) Check for leaks, correct any you may find.

(d) Check all valves, replace if necessary.

(e) Clean and dry interior and exterior parts.

(f) Keep accurate records of maintenance and repairs.

A REVIEW OF CHLORINE ACCIDENTS

(Excerpts from article appearing in Journal of American Water Works Association, Volume 30, Number 10)

The following case histories of chlorine accidents illustrate many of the common errors in handling this gas. Please read for your own information.

Case 1. Cylinder Accident. Wall of cylinder in service failed. Operators were not provided with gas masks. Nearby industrial company sent men with all-service gas masks. Persons attempting to use them were all gassed-none severely. The all-service gas masks were later found to be in poor condition.

Prevention Comment. 1. Cylinder had passed required five year inspection for strength. Internal examination would have revealed defects not registered during required pressure test. 2. A poor gas mask is worse than no gas mask.

Case 2. Cylinder Accident. Cylinder had been in service for two years in this small water plant. It developed a tight valve during the 23rd month of its continuous use. A tight valve complaint was made to the shipper. The shipper's employee, upon noticing that the leak did not increase when the auxiliary valve was wide open, assumed that the cylinder valve had "frozen" in a nearly closed position. He failed to check the auxiliary valve which, incidentally, was plugged. He removed the auxiliary valve and found to his dismay that the cylinder valve had frozen in an open position. He endeavored to cap it, unsuccessfully. He threw it in a shallow warm stream. He pulled several other "iron man" stunts, finally was overcome and was sent to the local hospital. He recovered and was sent home in three hours. Firemen, with all-service gas masks in good condition, recovered the cylinder and capped it.

Prevention Comment. The cylinder had been in service too long for the valve packing to remain resilient. The stem of such a valve should be opened wide and closed tightly at least once daily. Six months of continuous service is all that the average customer may reasonably expect of a cylinder valve. The shippers employee used poor judgment in that he did not completely investigate his problem before removing the auxiliary valve and he used very poor judgment in not having his gas mask available when he removed the valve.

Case 3. Cylinder Accident. Cylinder developed a tight valve in service. Attendant on duty disconnected it from line thinking that the cylinder valve was closed. It was not closed and substantial quantities of chlorine were released into the

building. The attendant donned a gas mask and attempted to remove the cylinder from the building. The mask was improperly adjusted to the contour of his face and he received a severe dose of chlorine. His superior donned the gas mask correctly and removed the cylinder from the building. He capped the valve against pressure and thus stopped the escape of chlorine. Shippers employees, arriving later at the scene, closed the valve after loosening the packing. Attendant was taken to hospital and held four hours for observation and sent home for recovery. He lost two days from work. Three other employees were slightly gassed.

Prevention Comment. This is a clear case of negligence. The employee could have closed the valve by first loosening the packing nut. He could have avoided injury to himself and others by knowing how to use a gas mask. He could have avoided injury by being certain that the valve was closed before disconnecting the cylinder.

Case 4. Cylinder Accident. Customer didn't want to buy a chlorinator. He attempted to chlorinate his supply by discharging gaseous chlorine from a 100-pound cylinder through a rubber tube into an open barrel through which cold water was continuously running to the plant discharge line. An official reporting trouble, said in part "...we tried to open the (cylinder) valve a trifle and opened it too much. We (later) tried to close the valve and found it frozen. We filled the reservoir with gas and almost killed a man or two. We finally managed to unscrew the hose and put a cap on the valve outlet." Subsequent investigation indicated that no one was seriously injured.

Prevention Comment. None needed.

Case 5. Two cylinders taken from storage, alleged to be leaking were thrown into the intake pond. The warm water (August) did not absorb the chlorine and the valves were rapidly disintegrated under water. Chlorine gushed up into the air and damaged 61 trees adjacent to the pond. No personal injuries.

Prevention Comment. Cylinder should never be submerged in ponds or other bodies of water if the water is warmer than 49.2°F. The chlorine leak will become worse rapidly and the cylinder will quickly get out of control and do much damage to the adjacent premises. A sure way in all cases is to blow the chlorine into a lime slurry or caustic soda solution. 1.25 lb. caustic soda or lime will be needed for each pound of chlorine to be absorbed.

Case 6. When operator attempted to discharge cylinders he was gassed because the valve on the cylinder being disconnected was not closed, but "frozen" open. The operator spent one day in the hospital recuperating from his negligence. Complete recovery was made.

Prevention Comment. It is obvious that one must be certain that cylinder valves are tightly closed before disconnecting them.

PRECAUTIONS

IN CHLORINATION OPERATION*

1. Chlorine gas is extremely irritating to the eyes, mouth, throat, and nose. Repeated exposures to low concentrations may have an effect on the lungs. Because chlorine is heavier than air, exhaust ducts for venting fumes should be installed in the lowest part of the room. The switches for the exhaust fans should be outside of the chlorinator room.

2. Chlorine is very corrosive when moist. Iron pipe can be used for dry gas. Parts coming in contact with chlorine solution must be made of silver, tantalum, glass, rubber, or certain synthetic compounds.

3. Chlorine reacts with greases, oils, ethyl alcohol, and ether to produce solid compounds which clog fittings and parts. Carbon tetrachloride is the best cleanser to remove these compounds. Be sure room is well ventilated while using tetrachloride.

4. High-test hypochlorites may explode if they come in contact with organic matter or other chemicals.

5. Withdrawing Chlorine from Cylinders: A cylinder received from the chlorine supplier may legally contain about 88% liquid chlorine by volume and 12% dry chlorine gas at 79°F. The cylinder pressure keeps most of the chlorine in liquid form at ordinary temperatures.

   When the cylinder valve is opened and gas is withdrawn, pressure in the cylinder is relieved. Then more liquid passes into gaseous form. This change from liquid to gas requires heat (obtained from the surrounding air through the cylinder walls).

   (a) If gas is drawn off too quickly, so much heat is taken from the surrounding air that frost forms on the cylinder. Freezing slows down passage of the gas. Maximum safe rates for drawing off chlorine are:

   40-50 pounds per day from 150-pound cylinders

   400 pounds per day from 1-ton cylinders

*Source: Adapted from Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Manual No. 85-13, Reprint June 15, 1968. pp. 120-122.

(b) NEVER try to speed up withdrawal of chlorine gas by heating the cylinder or placing it in hot water. This might melt fusible plugs in the cylinder and let the gas escape.

(c) Chlorine gas will turn back to liquid in the piping between the cylinder and the pressure-reducing valve in the chlorinator if its temperature is below the temperature of the gas in the cylinder. This would cause the chlorinator to operate improperly. To prevent the gas from turning back to liquid, install the chlorine cylinder where its temperature will be the same or slightly lower than room temperature at the control unit. Do not place a cylinder near a heating unit, in front of a window, or in direct sun rays. Do not allow cold drafts on chlorine piping.

If room temperatures are low and heating is required to keep chlorine gas from turning to liquid in the piping, limit the temperature to 100°F.

(d) Chlorine ice (chlorine hydrate) sometimes forms inside the chlorinator and interferes with operation. It is caused by low tray-water temperature. If the formation of chlorine ice is not severe, it can be prevented by hanging a 100-watt light bulb against the bell. Otherwise, temper the tray-water by using a hot-water coil or small electrical heating element which is available from the chlorinator manufacturer.

(e) Use wrought-iron, steel, or copper pipe to conduct dry chlorine gas from the cylinder to the chlorinator. The pipe must be extra-heavy type for 250-pound service. The pipe should be at least 3/4 inch nominal size.

To make up threaded joints: use a paste of litharge and glycerin. DO NOT use ordinary pipe dope. Support the piping securely. Slope it so it drains back to the cylinder without traps or snags that would collect reliquified chlorine gas.

(f) Open chlorine valves slowly and carefully. Use a wrench of proper size---not longer than 6 inches. NEVER use an extension on the wrench. Open valves only part way---one full turn of the valve stem permits maximum discharge. Tap the wrench lightly to aid in the operation of stuck valves.

(g) Close the valves as soon as the cylinder is empty. Use a crayon and write "EMPTY" near the valve. Return the empty cylinder to producer.

6. Locating Leaks: You will often notice a leak from the sharp chlorine odor. If you think there is a chlorine leak, put on a gas mask. Locate the leak by holding the mouth of an unstoppered bottle of ammonia-water close to pipes, fittings, and valves. If there is a leak, heavy white fumes will appear. IF THE LEAK IS IN THE LINES---shut off the flow of chlorine and repair the leak. IF THE LEAK IS IN THE CYLINDER HEAD---and cannot be stopped by closing the valve, run the gas into a caustic soda solution: A solution of 25 pounds of caustic soda in 10 gallons of water will absorb 20 pounds of chlorine gas.

7. A gas mask should be used when handling chlorine. Masks should be located near, but outside of, chlorine feeder and storage areas. Inspect and maintain gas mask on a regular basis.

GAS CHLORINATORS*

MAINTENANCE AND REPAIR

1. Inspect for Leaks
2. Operate Chlorine Valves
3. Check Water System
4. Check Gas System
5. Clean Cabinet & Critical Working Parts
6. Disassemble or Operate Hard-rubber Threads, Valves, and Parts
7. Overhaul
8. Check Vacuum Relief
9. Examine Solution Tube

* * * * * *

1. INSPECT FOR LEAKS (Every Day). Check chlorinator and all piping for chlorine or water leaks. All chlorine leaks are serious because they increase rapidly in size and cause extensive corrosion and damage.

   To locate leaks, hold the mouth of an unstoppered ammonia-water bottle (or cloth dipped in ammonia-water) near all joints, valves, and along piping. Any white fumes mean there is a leak. Keep ammonia bottle tightly stoppered when not in use to prevent loss of strength. Use only litharge and glycerin cement in making all metal screwed-pipe connections. Do not use grease or oil.

2. OPERATE CHLORINE VALVES (Every Day). Open and close all chlorine valves to prevent threads on the valve stems from becoming set in one position. Do not use force in closing a valve. Check stuffing boxes. Repair or replace any faulty valves at once.

3. CHECK GAS SYSTEM (Every Day). Check to make sure all piping and parts carrying chlorine gas are operating properly. Check meters, pressure-reducing valves, shutoff valves, and tubing. Disassemble and clean when necessary. At first sign of weakening, replace any faulty parts.

4. CHECK VACUUM RELIEF (Every Day). Make sure the entire assembly operates properly. Make sure the relief-hose line is not plugged. Insects like mud-daubers may plug these lines by building nests in them.

5. CLEAN CABINET & CRITICAL WORKING PARTS (Once a Week). Clean chlorinator cabinet, glass parts, floats, meters, and other parts where dirt might interfere with operation. Clean unpainted metal. Then cover unpainted metal with a film of petrolatum (or similar protective compound).

*Source: Adapted from Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Manual No. 85-13, Reprint June 15, 1968. pp. 411-413.

6. CHECK WATER SYSTEM (Once a Month). Clean the water strainers. Check pressure-reducing valve for proper operation. See that float valves are properly controlling water levels. There should be little or no leakage or splashing. See that water levels are kept at proper elevations. See that ejectors have their ample capacities. If they do not, remove and clean with muriatic acid.

7. DISASSEMBLE OR OPERATE HARD-RUBBER THREADS, VALVES, AND PARTS (Once Every Three Months). Hard-rubber threads or parts freeze or stick when not operated for long periods. This causes them to break when parts are disassembled. To keep the threads from freezing, operate all parts needed to keep chlorinator in service.

   Caution: Use no tools on hard-rubber parts. Tighten hard-rubber parts only finger tight. Cover pipe threads with graphite grease GH.

8. OVERHAUL (Once a Year). Disassemble and clean all chlorinator parts. Paint chlorinator cabinet with rust-resisting paint inside and out. Carefully examine each chlorinator part. Reassemble and check for proper operation.

   (a) The only safe liquids for cleaning chlorine lines are wood alcohol and carbon tetrachloride. After cleaning, let it evaporate to dryness. Ethyl alcohol or ether must not be used because they are converted by chlorine into solid waxy substances which are difficult to remove. When water and chlorine combine, a highly corrosive acid results.

   (b) Do not use grease or oil at points where they might come in contact with chlorine. Oil or grease reacts with chlorine and forms a voluminous frothy substance.

   (c) Keep everything around the chlorine equipment dry and well-ventilated. An electric fan will work. Condensation from moist air may corrode scales and other equipment around the cylinder. NEVER apply direct heat to dry the cylinder.

   (d) It is dangerous to heat chlorine cylinders or containers above normal room temperature. Make sure the cylinder is not exposed to direct sun heat. Do not place the cylinder near steam or hot water lines or other sources of heat.

   (e) Use a new lead gasket each time a valve or tube is connected or when replacing empty chlorine cylinders. Use only one lead gasket.

9. **EXAMINE SOLUTION TUBE** (Once a Year). Check tubing for cracks or worn spots that might cause leaks. Check tubing for kinks and for mineral deposits that would restrict discharge. To remove iron or manganese deposits from diffuser tube: add 10% solution of hexametaphosphate or septaphosphate to make-up water, at a rate of 1 drop per minute. To add reagent: attach rubber hose to bottle containing treatment solution and place pinch clamp on rubber hose. Turn bottle upside down and adjust pinch clamp for proper feed rate. Continue until deposit is removed.

Name: _____

This evaluation may be completed orally or in writing.

Directions: In the space provided, write the word "True" or "False" next to each item. If you answer "False" write the correct answer on the line under the question.

1. *True* There should be plenty of fresh air from windows or exhaust fans where the chlorinator is located.

2. *False* The temperature around a chlorinator should be kept at about 50°F.
The temperature should be kept between 65° and 70°F.

3. *True* The chlorinator room should be as dry as possible.

4. *False* It is not necessary to have lights in the room where the chlorinator is located.
The room must be well lit for performing maintenance and repairs.

5. *False* Small chlorine leaks will usually close up by themselves.
Even small leaks should be repaired immediately. They will not close up by themselves.

6. *False* An open bottle of ammonia water should be kept near the chlorinator for testing for leaks.
Ammonia should be kept tightly capped or it will lose its strength.

7. *True* The "Operator's Manual" supplied with a chlorinator includes directions for performing maintenance and repairs on the chlorinator.

8. *False* Two gaskets are better than one for most joints. *Only one gasket should be used. Additional gaskets increase the possibility of leaks.*

9. *True* All internal parts should be completely dry after they are cleaned.

10. *True* Clear lacquer is a good protective coating for the plated parts of a chlorinator.

11. *False* Aromatic spirits of ammonia from the local drugstore is good for detecting chlorine leaks. *This is of little value in detecting leaks. Non-sudsing ammonia from the grocery store or aqua-ammonia from the drugstore are good for detecting leaks.*

12. *True* All chlorine containers have a fusible plug designed to melt at high temperatures. This is to relieve dangerous pressure.

13. *True* The higher the temperature is, the greater the pressure is in a gas chlorinator.

State of West Virginia
Department of Education
Charleston
25305

DANIEL B. TAYLOR
STATE SUPERINTENDENT
OF SCHOOLS

(Chlorination #29)

Note to Operators:

It is necessary that you learn how to give mouth-to-mouth resuscitation properly for this competency. There is a "dummy" designed to practice on. Your local vocational school or Red Cross may have a resuscitator dummy available for your use. Perhaps you may participate in instruction on how to perform mouth-to-mouth resuscitation at your nearest vocational school.

If you cannot find a resuscitator dummy to use for this competency, please contact your evaluator.

COMPETENCY: Demonstrate the use of correct first aid procedures for someone who has been overcome with chlorine gas.

Objective: List, in proper order, the steps which should be taken if a person has been overcome with chlorine gas.

Objective: Demonstrate the ability to correctly operate equipment for the administration of oxygen.

Objective: Demonstrate the ability to administer mouth-to-mouth resuscitation correctly.

RESOURCES:

(a) Operator's manual for gas chlorinator.

(b) "A Revue of Chlorine Accidents" Resource Sheet I, Competency # 28.

(c) "The Chlorination of Water", West Virginia State Department of Health, Division of Sanitary Engineering, p. 3. *-Buff Appendix-*

LEARNING ACTIVITIES:

(a) Read all resources listed above for information about helping a person who has been overcome by chlorine gas.

(b) Become familiar with the steps you should take in each of the following situations:

1. Liquid chlorine has been spilled on a person. His/her skin and clothing are covered with chlorine.
2. Liquid chlorine has splashed into a person's eyes.
3. A person's eyes have been exposed to a large quantity of chlorine gas.
4. A person has swallowed some liquid chlorine.
5. A person has inhaled a large amount of chlorine gas. This person is still breathing.
6. A person has inhaled a large amount of chlorine gas. This person has stopped breathing.

(c) View the movie "The Breath of Life" that shows how to administer mouth-to-mouth resuscitation.

(d) Attend a demonstration on how to operate the equipment to administer oxygen to a person and how to administer mouth-to-mouth resuscitation to a person.

EVALUATION ACTIVITIES:

(a) When you feel you are ready, complete Evaluation Form #29. This form contains questions about the steps you would need to take if someone was overcome by chlorine gas. You must answer all questions correctly. You may not use references.

(b) After you have completed Evaluation Form #29 correctly, notify your instructor. You must now demonstrate your ability to:

1. Operate equipment to administer oxygen to a person correctly.
2. Administer mouth-to-mouth resuscitation properly.

(Chlorination #29)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

This evaluation may be completed orally or in writing.

Directions: Fill in the correct answer to each question below.

1. **A man has chlorine on his skin and clothes. What first aid would you give?**
Remove clothes under shower. Wash chlorine off skin with large amounts of water. Do not apply salves or ointments for 24 hours.

2. **A child's eyes have been exposed to a strong concentration of chlorine gas. What first aid would you give?**
Flush the eyes with running water for at least 15 minutes. Call a physician at once. No oils or oily ointment should be used.

3. **A person has swallowed some chlorine. He is still conscious. What first aid would you give?**
Make him drink large amounts of lime water, milk of magnesia or plain water if the others are not readily available. DO NOT GIVE SODIUM BICARBONATE. Call physician immediately.

4. **A woman has inhaled a large amount of chlorine gas. She is still breathing. What first aid would you give?**
Place her on her back with her head and back elevated. Keep her warm -- use blankets if necessary. Call physician immediately.

5. **A man has inhaled a large amount of chlorine gas. He has stopped breathing. What first aid would you give?**
Lay him on his back. Administer mouth-to-mouth resuscitation. Have someone call a physician immediately. Continue resuscitation until physician arrives. Administer oxygen if you are qualified to do so.

COMPETENCY: Demonstrate the ability to prepare comparable hypochlorite solutions with uniform chlorine strength using three different strength hypochlorite compounds.

Objective: Identify three sources of chlorine that can be used to make hypochlorite solutions.

Objective: Perform the correct mathematical calculations to determine the strength of hypochlorite solutions.

RESOURCES:

(a) Laundry bleach (5% sodium hypochlorite).

(b) Commercial laundry bleach (15% sodium hypochlorite).

(c) Dry hypochlorite (70% calcium hypochlorite).

(d) "Preparing Hypochlorite Solutions" Resource Sheet I.

(e) "Preparing Hypochlorite Solutions" Resource Sheet II.

(f) Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224, pp. 157-58.

LEARNING ACTIVITIES:

(a) Read the recommended resources to find information about preparing hypochlorite solutions.

(b) Prepare a 1% chlorine solution (10,000 ppm) using *LAUNDRY BLEACH (5% sodium hypochlorite)*.

The easiest way to prepare a sodium hypochlorite solution is by *dilution*. To dilute a one gallon bottle of laundry bleach (5% sodium hypochlorite) to a 1% solution: (Note- the % is expressed as a decimal- 1 % = .01)

$$\text{Feed Unknown (gallons)} = \frac{\text{gallons of sodium hypochlorite} \times \text{decimal percent of sodium hypochlorite}}{\text{desired strength of solution (decimal percent)}} = \boxed{\quad} \text{ ANSWER}$$

Fill in the equation to:

$$\text{Unknown (gallons)} = \frac{1 \times .05}{.01} = \boxed{5 \text{ gallons}}$$

That means you must have 5 gallons of solution to have a 1% solution.

Here's another example: If you want to dilute a 5 gallon bottle of laundry bleach (5% sodium hypochlorite) use the same formula.

$$\text{Feed Unknown (gallons)} = \frac{\text{gallons of sodium hypochlorite} \times \text{decimal percent of sodium hypochlorite}}{\text{desired strength of solution (decimal percent)}} = \boxed{} \text{ ANSWER}$$

Fill in the equation to:

$$\text{Unknown (gallons)} = \frac{5 \times .05}{.01} = \boxed{25 \text{ gallons}}$$

(c) Prepare a 1% chlorine solution (10,000 ppm) using *COMMERCIAL LAUNDRY BLEACH (15% sodium hypochlorite)*.

Use the same formula used above to dilute a 5 gallon bottle of commercial laundry bleach (15% sodium hypochlorite) to a 1% solution.

$$\text{Feed Unknown (gallons)} = \frac{\text{gallons of sodium hypochlorite} \times \text{decimal percent of sodium hypochlorite}}{\text{desired strength of solution (decimal percent)}} = \boxed{} \text{ ANSWER}$$

Fill in the equation to:

$$\text{Unknown (gallons)} = \frac{5 \times .15}{.01} = \boxed{75 \text{ gallons}}$$

(d) Prepare a 1% chlorine solution (10,000 ppm) using *CALCIUM HYPOCHLORITE (70%)*. Calcium hypochlorite is a dry chemical. It must be dissolved in water. Calcium hypochlorite compounds will retain their chlorine content for several months if they are stored in a cool area. Once a container is opened, loss of chlorine may occur, especially if exposed to moisture in the air. If exposed hypochlorite is used, more material may be needed to get the right chlorine concentration.

Assume that the chemical will be mixed in a 30 gallon drum. This is the size drum usually used in treatment plants in West Virginia.

To prepare a 1% chlorine solution (10,000 ppm) using calcium hypochlorite (70%) use the following formula:

$$\text{weight of chemical (pounds)} = \frac{\text{strength of solution (ppm)}}{120{,}000} \times \frac{\text{gallons of solution (gallons)}}{\text{strength of dry chemical (decimal percent)}}$$

$$\text{pounds of calcium hypochlorite} = \frac{10{,}000 \times 30}{120{,}000 \times .70} = \boxed{3.57 \text{ pounds}}$$

You need to dissolve approximately 3.6 pounds of 70% calcium hypochlorite in 30 gallons of water to prepare a 1% chlorine solution.

Remember: put about 90% of the solution into the hypochlorinator feed tank and *throw away the remaining solution.* The remaining solution contains the calcium precipitate that builds up and eventually clogs the feeder.

EVALUATION ACTIVITIES: You will be required to prepare three comparable hypochlorite solutions. You will be given the strength of the compounds and the formulas to use. You may use a calculator. All of your answers must be correct. You must show your calculations on the answer sheet. You may not use references.

After you have answered all three problems correctly, you must actually prepare the three solutions while your Evaluator observes you.

PREPARING HYPOCHLORITE SOLUTIONS*

Calcium Hypochlorite Solutions

Calcium hypochlorite is readily soluble in either warm or cold water, and very strong (concentrated) solutions can therefore be prepared. It reacts with water in the same manner as does chlorine gas to produce a solution of hydrochloric and hypochlorous acids, a highly corrosive solution. Therefore, the solution container must be made of corrosion-resistant material. Wood, ceramic, glass, plastic, or rubber-lined steel containers are suitable.

All hypochlorite solutions can cause skin burning and destroy clothing. When handling these solutions, such protective apparel as rubber gloves, rubber aprons, and goggles should be worn. Avoid splashing the solution. Accidental splashes of solution on the operator should be treated immediately by thoroughly washing all exposed parts of the body with ample quantities of water. Clothing also should be thoroughly washed before reuse.

In preparing the calcium hypochlorite solution, the operator should follow instructions furnished by the equipment manufacturer as to amounts of water and hypochlorite to be used. Usually a solution containing 1-2 percent of available chlorine is prepared. This solution should be prepared in a separate container and permitted to stand for 8-24 hr. before actual use to facilitate removal of insoluble compounds. The clear solution should then be siphoned or poured into the container supplying the feeder. A 24-hr. supply of solution is usually prepared. This procedure usually requires at least two containers.

Calculations for Calcium Hypochlorites

In some plants, records are kept of the number of pounds of dry hypochlorite used over a 24-hr. period, and these records are then used to calculate the chlorine dosage in ppm. Thus, the dosage is the number of pounds of available chlorine added to each million pounds of water. The method of calculation is illustrated in the following example:

What is the chlorine dosage when 30 lb of 70 percent HTH (a calcium hypochlorite compound) is used to treat 300,000 gal. of water?

*Source: Basic Water Treatment Operator's Manual, No. M18, American Water Works Association, 2 Park Avenue, New York, N.Y. 10016, 1971. pp. 49-53.

By 70 percent is meant that each 100 lb. of HTH contains 70 lb. of available chlorine. This percentage must be divided by 100 to obtain the pounds of available chlorine in each pound of HTH; in this case 0.7 lb. chlorine/lb. of HTH. Thus 30 X 0.7 = 21 lb. of chlorine used. 300,000 gal. of water equals 300,000/1,000,000 = 0.3 mil. gal. Thus, the chlorine used per mil. gal. is 21 ÷ 0.3 = 70 lb. Since 1 ppm equals 8.3 lb./mil. gal., 70 must be divided by 8.3 to obtain the ppm dosage figure. Thus, 70 ÷ 8.3 = 8.4 ppm, the chlorine dose in this example.

Hypochlorite solutions are often made up as 1 or 2 percent available chlorine solutions. A 1 percent solution of chlorine can be taken as containing 0.08 lb./1 gal. solution of chlorine. A 2 percent solution contains 0.16 lb./gal. chlorine. A 2 percent chlorine solution can be prepared by dissolving 4 oz. HTH/gal. of water. This calculation is exact enough for practical purposes.

A 1.7 percent HTH solution (2.5 oz. HTH/gal. of water) produces a chlorine solution each gallon of which has a strength of 0.10 lb. of chlorine. Such a concentration simplifies record keeping. Example:

Assume that 15 gal. of such a 1.7 percent HTH solution is used to treat 750,000 gal. of water. What is the chlorine dose in lb./mil. gal. and in ppm?

Solution:

1). The amount of 1.7 percent HTH solution used per mil. gal. of water is (15/750,000) X 1,000,000 = 20 gal.
2). 20 gal. of this HTH solution contains 20 X 0.1 = 2 lb. of chlorine. The chlorine dose is 2 lb./mil. gal.
3). A ppm is equal to 8.3 lb./mil. gal. Thus, the parts per million of chlorine in this problem is 2 ÷ 8.3 = 0.24 ppm.

High-test calcium hypochlorite compounds will retain their chlorine content for many months when properly stored in cool areas. Loss of chlorine can occur, however, once a container is opened, particularly if the contents are exposed to moisture in the air. If exposed hypochlorite is used, more material may be required to obtain the desired chlorine concentrations.

Preparing Sodium Hypochlorite Solution

Sodium hypochlorite is supplied only in solution form containing 5-17 percent available chlorine. Being in solution form, it is ready for use as delivered. The delivered solution concentration of chlorine is, however, usually too high

for use in hypochlorinators and must be diluted with water. The same precautions used in handling solutions of calcium hypochlorite should be used with sodium hypochlorite solutions. All containers also must be corrosion-resistant. Instructions in the equipment manufacturer's manual should be closely followed.

Unlike calcium hypochlorite, no sediment problems occur with sodium hypochlorite solutions. And this chemical can be diluted in the container that supplies the feeder. Two containers are desirable so that any errors in dilution can be corrected before the solution is drawn into the feeder.

Calculations for Sodium Hypochlorite

1. It is essential to know how much water and sodium hypochlorite solution must be used to obtain a desired concentration of chlorine in the solution going to the feeder. This information is obtained with the following equation:

$$\text{Gallons of concentrated solution} = \frac{\text{Gallons of dilute solution} \times \text{Diluted \%}}{\text{\% of concentrated solution}}$$

As an example, how many gallons of 15 percent sodium hypochlorite solution are required to prepare 55 gal. of 2 percent solution? The equation becomes $(55 \times 2)/15 = 7.33$ gal.

Therefore, a mixture of 7 1/3 gal. of a 15 percent sodium hypochochlorite solution and 47 2/3 gal. of water will give 55 gal. of solution containing 2 percent available chlorine.

2. The following equations may be used for either calcium- or sodium-hypochlorite solutions. The first is used for calculating the chlorine dosage.

$$\text{Chlorine dosage (ppm)} = \frac{\text{Gallons of solution} \times \text{\% chlorine} \times 10{,}000}{\text{Gallons of water treated.}}$$

For example, what is the chlorine dosage when 40 gal. of a 1.5 percent chlorine solution are used to treat 500,000 gal. of water? The equation becomes

$$\text{Chlorine dosage (ppm)} = 40 \times 1.5 \times 10{,}000/500{,}000 = 1.2 \text{ ppm.}$$

3. To determine the quantity of solution required to treat a certain amount of water, the following equation is used:

$$\text{Gal. of solution} = \frac{\text{Desired dosage (ppm)} \times \text{Gallons water treated}}{\text{\% chlorine} \times 10{,}000}$$

For example, how many gallons of a 1 percent solution are needed to treat 200,000 gal. of water to obtain a dosage of 0.8 ppm? The equation becomes

$$\frac{0.8 \times 200,000}{1 \times 10,000} = 16 \text{ gal.}$$

Sodium hypochlorite solutions will gradually lose strength during storage. Storage for 100 days can result in 50 percent loss in strength. For this reason, sodium hypochlorite storage should be limited to about one month or six weeks.

Metering Flow

Once the hypochlorite solution of the desired chlorine concentration has been prepared, means must be available to feed it accurately in proper amounts. This may mean a few gallons or as many as 500-1,000 gpd. Many equipment manufacturers offer hypochlorinators to meet this wide range of requirements. Naturally, these feeders are offered in different sizes to meet specific needs. For example, feeding capacities range from 0-20, 0-60, and 30-1,000 gpd.

To meet the varying conditions that may exist in chlorination of water supplies, hypochlorinators that are powered by water pressure, electric power, compressed air, or gasoline engines can be obtained.

Although other methods of metering are employed in various hypochlorinators, discussion here will be limited to the so-called positive-displacement-type feeders. Stated very simply, they suck specific amounts of solution into containers and then expel the same amounts to the points of chlorine application. Most feeders of this type use the diaphragm principle.

The amount of solution that is fed can be regulated by the length of stroke of the push rod. If the diaphragm moves only a short distance, small amounts of solution will be sucked into the feeder. Longer strokes will feed more solution. Many hypochlorinators permit regulation of the length of stroke merely by turning a control knob on the machine, even while the equipment is in operation.

Most hypochlorinators also provide means for regulating amounts of solution by changing the number of strokes over a period of time, sometimes from as low as four to more than 60 strokes per minute. Alterations in stroke rate are usually made by changing belts or gears.

Hypochlorinator design can differ considerably between manufacturers. Manufacturer's instruction bulletins should be consulted for specific models.

One type of diaphragm unit is termed a single, or simplex head feeder. When very large amounts of hypochlorite solutions must be fed, units with more than one head can be supplied. A hypochlorinator with two heads (dual head or duplex) will permit the feeding of twice as much solution. Triple-head units are also available. The term "head" can apply to other diaphragm plunger-type feeders.

The simplest type of hypochlorinator is designed for manual feed-rate adjustment. Feed rate changes are accomplished by turning a knob or changing belts or gears. More sophisticated units can be operated automatically to the extent of changing feed rates to conform to amounts of water passing through plants.

PREPARING HYPOCHLORITE SOLUTIONS*

Rate of feed of hypochlorinators is found from the loss of volume in gallons of solution by determining change in depth of solution in its container. Knowing the solution strength, the pounds chlorine used can be calculated. Substituting this figure in the equation for the loss in weight, the pounds per day rate can be determined.

Preparing Hypochlorite Solutions:

(1) Available chlorine content of the chlorine compound used must be known in order to calculate the rate of hypochlorite-solution feed. Available chlorine is usually marked on the container as a percentage of weight. Values generally are as follows:

Chemical	Available Chlorine
Calcium hypochlorite	70 percent
Sodium hypochlorite (liquid)	10 percent (varies)
Chlorinated lime	35 percent

To find the actual weight of chlorine compound to be added, use the equation:

$$\text{Pounds of chemical required} = \frac{\text{pounds of chlorine required X 100}}{\text{percent available chlorine}}.$$

(2) To find amount of 1 percent dosing solution needed to treat a given quantity of water with desired dosage, use the equation:

$$\text{Gallons dosing solution required} = \frac{\text{Gallons water treated X desired chlorine dosage in ppm}}{10{,}000}.$$

(3) To prepare various quantities of 1 percent dosing solution use the amounts given in table on following page.

(4) To find rate of feed of chlorine in gallons per day, use the equation:

$$\text{Chlorine rate of feed in gallons per day} = \frac{\text{mgd flow X ppm dosage}}{\text{\% strength of dosing solution X 10,000}}.$$

Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, Reprint dated June 15, 1968. pp. 118-119.

(5) To find pounds of chlorine compound needed to prepare dosing solution of a desired strength, use the equation:

$$\text{Pounds of compound required} = \frac{\text{\% strength of solution} \times \text{gallons of solution required} \times 8.34}{\text{\% available chlorine in compound}}.$$

(6) To find the gallons of hypochlorite stock solution needed to prepare dosing solution of a required strength, use the equation:

$$\text{Gallons stock solution required} = \frac{\text{\% strength of dosing solution} \times \text{gallons of dosing solution required}}{\text{\% strength of stock solution}}.$$

Cautions:

(1) Make dosing solutions strong enough so the hypochlorinator can be adjusted to feed one-half its capacity per day or less.

(2) Avoid using a calcium hypochlorite dosing solution stronger than 2 percent, even if it is necessary to set the machine to feed its full daily capacity.

(3) If a calcium hypochlorite solution stronger than 2 percent is required when the feed is set at maximum, small amounts of sodium hexametaphosphate in the solution will permit maximum concentrations up to 5 percent. Solutions of sodium hypochlorite may be fed in greater concentrations.

AMOUNTS OF CHLORINE COMPOUNDS USED TO PREPARE 1 PERCENT DOSING SOLUTION

Gallons of dosing solution	Calcium hypochlorite 70%		Chlorinated Lime 35%		Gallons of hypochlorite stock solution			
					15%	10%	6%	5%
	Pounds	Ounces	Pounds	Ounces				
5.....	0	9-1/2	1	3	1/3	1/2	5/6	1
10.....	1	3	2	6	2/3	1	1-2/3	2
15.....	1	12-1/2	3	9	1	1-1/2	2-1/2	3
20.....	2	6	4	12-1/2	1-1/3	2	3-1/3	4
25.....	2	15-1/2	5	15-1/2	1-2/3	2-1/2	4-1/6	5
30.....	3	9	7	2-1/2	2	3	5	6

Note: A 1-percent solution contains 10,000 ppm available chlorine.
1 gallon of 1% solution weighs about 8.43 pounds.

1. Prepare a 1% chlorine solution using 5 gallons of laundry bleach (5% sodium hypochlorite).

$$\text{Feed Unknown (gallons)} = \frac{\text{gallons of sodium hypochlorite} \times \text{decimal percent of sodium hypochlorite}}{\text{strength of solution (decimal percent)}} = \boxed{25 \text{ gallons}}$$

ANSWER

Solution to Problem:

$$\textit{Feed Unknown (gallons)} = \frac{5 \times .05}{.01} = \boxed{\textit{25 gallons}}$$

2. Prepare a 1% chlorine solution using 1 gallon of commercial laundry bleach (15% sodium hypochlorite). Use the same formula as above.

$\boxed{15 \text{ gallons}}$
ANSWER

Solution to Problem:

$$\textit{Feed Unknown (gallons)} = \frac{1 \times .15}{.01} = \boxed{\textit{15 gallons}}$$

3. Prepare a 1% chlorine solution using calcium hypochlorite (70%). Assume you are mixing the solution in a 30 gallon drum.

Use the formula below:

$$\text{pounds of calcium hypochlorite} = \frac{\text{strength of solution (ppm)}}{120{,}000} \times \frac{\text{gallons of solution (size of mixing drum)}}{\text{strength of dry chemical (decimal percent)}} =$$

$\boxed{3.57 \text{ pounds}}$
ANSWER

Solution to Problem:

$$\textit{pounds calcium hypochlorite} = \frac{10{,}000 \times 30}{120{,}000 \times .70} = \boxed{\textit{3.57 pounds}}$$

4. After <u>correctly</u> completing the three problems above, have the operator actually prepare all three solutions.

COMPETENCY: Demonstrate the proper use of a hypochlorinator.

Objective: Describe an appropriate location for a hypochlorinator.

Objective: Demonstrate the proper procedure for performing a routine maintenance check on a hypochlorinator.

Objective: Demonstrate the ability to clean interior and exterior parts and perform minor repairs on a hypochlorinator.

Objective: Demonstrate the ability to prepare a hypochlorite solution correctly and maintain a uniform solution in the hypochlorinator feed tank.

RESOURCES:

(a) "Hypochlorinators" Resource Sheet.

(b) Operator's manual for hypochlorinator

(c) BASIC WATER TREATMENT OPERATOR'S MANUAL, No. M 18, American Water Works Assoc., 2 Park Ave., New York, N. Y. 10016, 1971. pp. 49-54.
-Yellow Appendix-

LEARNING ACTIVITIES:

(a) Read the resources listed above to find background information about hypochlorinators.

(b) Under supervision of the instructor, practice the steps involved in performing a routine maintenance check on a hypochlorinator. Use the operator's manual as a reference.

(c) Under supervision of the instructor, clean the internal and external parts of a hypochlorinator:
1. Remove deposits by brushing and rinsing. For stubborn deposits, use a 5% solution of hydrochloric acid or acetic acid. These acids can burn the skin, so rubber gloves should be worn.
2. Replace all worn or damaged feeder parts.
3. Use the operator's manual as a reference.

(d) Practice keeping a record of each maintenance check and repair done on a hypochlorinator. Include date, status of parts, parts cleaned, and parts repaired.

(e) Under supervision of the instructor, prepare a hypochlorite solution correctly and explain how you would maintain a uniform solution in the hypochlorinator feed tank.

EVALUATION ACTIVITIES:

(a) Complete Evaluation Form #34. You must answer every question correctly. You may use the operator's manual as a reference.

(b) After you have completed Evaluation Form #34 correctly, notify your instructor that you are ready to demonstrate your ability to operate and maintain a hypochlorinator. You will be evaluated on the following criteria:

Maintenance check, cleaning, and minor repairs

(a) Demonstrate the proper use of all necessary protective equipment and clothing.

(b) Make sure the hypochlorinator is feeding correct amount of hypochlorite solution.

(c) Perform routine maintenance check.

(d) Clean interior and exterior parts.

(e) Keep accurate record of maintenance and repairs.

HYPOCHLORINATORS*

Hypochlorinators, or solution feeders, introduce chlorine into the water supply in the form of hypochlorite solution. They are usually modified positive-displacement piston or diaphragm mechanical pumps. However, hydraulic displacement hypochlorinators are also used. Selection of a feeder depends on local conditions, space requirements, water pressure conditions, and supervision available. Fully automatic types are actuated by pressure differentials produced by orifices, venturis, valves, meters, or similar devices. Care is necessary in their installation in mains to avoid restricted flows, which may limit fire flows. Hypochlorinators are sometimes used as standby equipment for gas chlorinators. Portable equipment is also available which may be used for main disinfection or during emergencies. They can also be used to feed chemicals for scale and corrosion control. Common types of hypochlorinators are described below.

(1) Proportioneers Chlor-O-Feeder. The Proportioneers Chlor-O-Feeder is a positive-displacement diaphragm-type pump with electric drive or hydraulic operating head. Maximum capacity of the most popular type, the heavy duty Midget Chlor-O-Feeder, is 95 gallons of solution in 24 hours.

(a) Semiautomatic Control. The motor-driven type may be cross connected with a pump motor for semiautomatic control. The hydraulic type can be synchronized with pump operation by means of a solenoid valve.

(b) Fully Automatic Control. Motor-driven types are made fully automatic by use of a secondary electrical control circuit actuated by a switch inserted in a disk or compound-meter gear box. This switch closes momentarily each time a definite volume of water passes through the meter, thus starting the feeder. A timing element in the secondary circuit shuts off the feeder after a predetermined number of feeder strokes; the number of strokes is adjustable. In the hydraulic type, the meter actuates gears in a Treet-O-Control gear box which in turn controls operation of a pilot valve in the water or air supply operating the feeder. The dosage rate is controlled by water flow through the meter, thus automatically proportioning the treatment chemical. Opening and closing frequency of the valve thus determines frequency of operation of the Chlor-O-Feeder.

Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, Reprint dated June 15, 1968. pp. 109-114.

(2) Wallace and Tiernan Hypochlorinator. The Wallace and Tiernan hypochlorinator is a positive-displacement diaphragm pump. A balancing valve allows water under full main pressure to flow into a chamber on the side of the diaphragm opposite the delivery side, thus balancing the diaphragm under equal pressures. The unit has a maximum capacity of 60 gallons of solution per 24 hours. Basic types and installation are the same as with the Chlor-O-Feeder.

(3) Wilson Type DES Hypochlorinator. The Wilson type DES hypochlorinator is a constant-rate, manually adjusted, electric-motor-drive, positive-displacement reciprocating pump for corrosive liquids. Maximum capacity is 120 gallons of solution per day. This unit is a piston pump with a diaphragm and oil chamber separating the pumped solution from the piston to prevent corrosion of working parts.

(4) Model S Hypochlorinator Manufactured by Precision Chemical Pump Corporation. The Model S hypochlorinator is a positive-displacement diaphragm pump with a manually adjustable feeding capacity of 3 to 60 gallons per day. A motor-driven eccentric cam reciprocates the diaphragm, injecting the solution into the main supply. Use of chemically resistant plastic and synthetic rubber in critical parts contributes to long operating life.

Location of Hypochlorinators. It is normal practice to locate hypochlorinators in the same room with other equipment such as pumps, switchboards, meters, and the like. However, due to the corrosiveness of the solutions it is better practice to locate them in a separate room. In any event, adequate floor drains should be provided for carrying away waste water, spillage, sludge, and wash-down water. A curbing at least 6 inches in height should be provided around the entire area used for this purpose whether in a separate room or in the same room with other equipment.

(Chlorination #31)

Evaluation Form
EVALUATOR'S COPY

Part I

Operator _____

Evaluator _____

Date _____

Directions: In the space provided write the word "True" or "False" next to each item. If you answer "False" write the correct answer on the lines under the question.

1. *True* Calcium hypochlorite compounds will lose their strength quickly when left standing in the atmosphere.

2. *True* Sodium hypochlorite must be supplied to the water system by a solution feeder.

3. *False* Only calcium hypochlorite solutions can cause skin burning and destroy clothing.
All hypochlorite solutions can burn skin and destroy clothing.

4. *True* Accidental splashes of hypochlorite solution should be treated by washing all exposed parts of the body with a lot of water.

5. *False* Sodium hypochlorite is supplied in crystal or solution form.
Sodium hypochlorite is supplied in solution form only.

6. *True* All containers for sodium hypochlorite or calcium hypochlorite should be corrosive-resistant.

7. *False* Sediment problems often occur with sodium hypochlorite solutions.
There are no sediment problems with sodium hypochlorite solutions. Sediment problems do occur with calcium hypochlorite solutions.

CHLORINATION*

Chlorination of public water supplies represents the most important process used in the production of water of a safe, sanitary quality. For the reasons outlined below the process is only as effective as the control that is exercised in insuring that all of the supply continuously receives chlorine in an amount, proportional to the flow, that will produce effective disinfection. Disinfection refers to the reduction of the bacterial population to a safe level, as contrasted to sterilization, which refers to the total destruction of the bacterial population. Chief attention must be directed to the careful selection and operation of chlorination equipment which will meet the requirements of the individual water supply and prevailing conditions.

Although other disinfectants have been tried and used in the past, and in a very few instances are still used, the best results have been obtained through the use of chlorine, either in the form of a gas or one of several compounds such as chloride of lime or sodium hypochlorite. In all cases, the active disinfectant is chlorine. Because of cost, dependability, efficiency and ease of handling, chlorine or chlorine compounds are practically always used. As a matter of fact, the term "chlorination" is generally used synonymously with disinfection in water works practice.

The first attempt to disinfect a public water supply in this country was in 1908. At that time equipment was installed to apply a solution of hypochlorite to treat the water supply for Jersey City. Subsequently, this was followed by installations at Elmira, Poughkeepsie, and Albany, all within New York State, as well as in a number of other municipalities throughout the country. In 1912, commercial equipment was developed for the application of gaseous chlorine to water supplies. Since that time, equipment has been developed for the wide and varied use that present water works practice require.

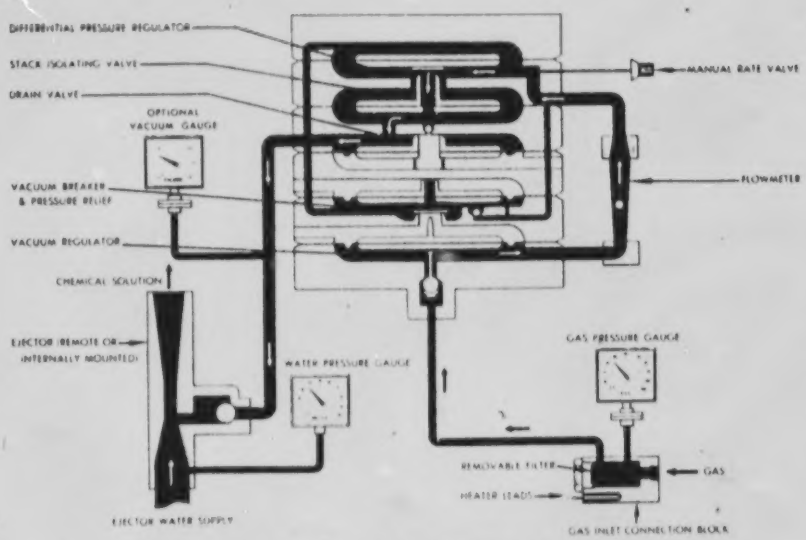
Chlorine may be applied either as a gas or as a solution, either alone or in conjunction with other chemicals. Regardless of the form of application, the quantity or dosage is controlled by special apparatus called chlorinators or hypochlorinators. Selection of the equipment depends on the particular installation.

*Source: Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224. pp. 153-169.

Gaseous Chlorination

At normal temperature and pressure, chlorine exists as a gas. However, it can easily be compressed to a point where it liquifies. This fact is used for its obvious advantages, as chlorine can be purchased and shipped in steel containers. In general water works practice, either 100- or 150-lb or one-ton containers are used, although chlorine is also available in tank car lots.

FIG 59

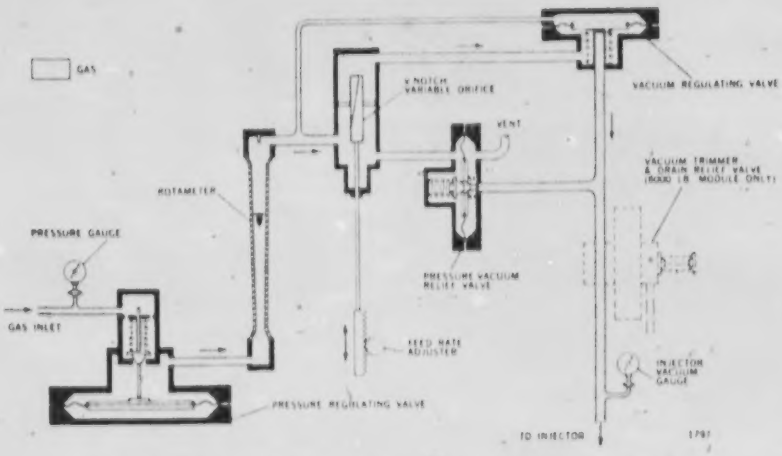


CHLORINATOR FLOW DIAGRAM (F & P)

51

Chlorinators consist of various combinations of pressure reducing valves actuated by mechanical diaphragms, or hydraulically operated floats, orifices or other types of meters, for measuring the rate of flow of the chlorine gas after it has been reduced to a uniformly low pressure. Devices are incorporated for making an aqueous solution of the gas and injecting this solution into the water. The type described above is the one in general use, and is commonly called a solution feed chlorinator. Figures 59, 60 and 61 are typical illustrations of flow diagrams for three different makes of chlorinators that may be purchased.

FIG 60

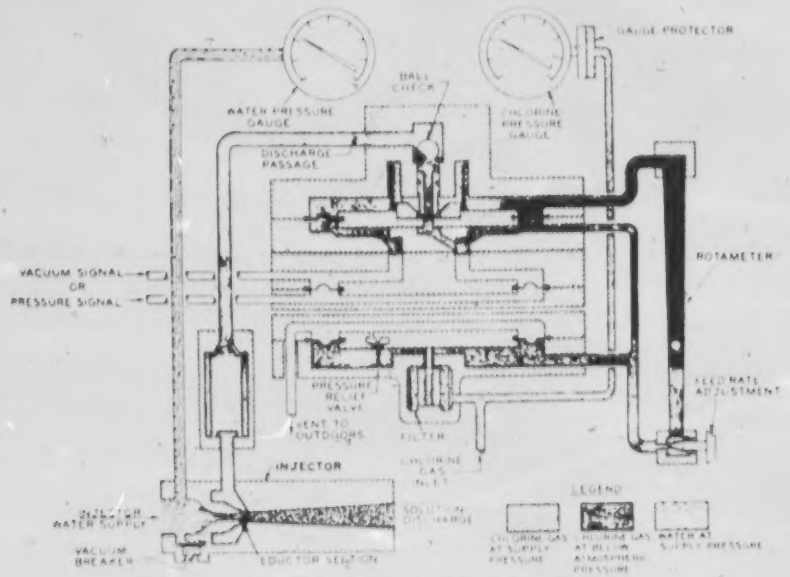


CHLORINATOR FLOW DIAGRAM (W&T)

At times, "dry feed" chlorinators are used when either water or electricity or both is unavailable at a site. This type of equipment is essentially the same as the solution feed type except there is no device for making and injecting an aqueous solution. The gas itself is piped directly into the water to be treated. Either solid silver or carborundum diffusers attached to the end of suitable piping are used at the point of application.

"Dry feed" equipment may give difficulty, at times, due to the formation of chlorine ice, particularly at low temperatures.

FIG. 61



CHLORINATOR FLOW DIAGRAM
(BUILDERS)

For proper operation, chlorination equipment requires care and attention. Manufacturers' recommendations and instructions should be made available to the operator of the equipment and should be followed. It is prudent for the operator to become thoroughly familiar with the equipment so he many become competent to make necessary adjustments and minor repairs.

Chlorine leaks may be detected by holding an open bottle of ammonia near the suspected points. If chlorine is escaping, whitish fumes of ammonium chloride will be formed and observed. As chlorine gas is an irritant, special care should be taken in order that none of the gas is inhaled. Gas masks should be stored in a readily accessible place, away from the chlorinator or chlorinator room so they are available for immediate use when needed. All chlorine leaks should be repaired as soon as possible to prevent personal injury or damage to equipment.

Chlorine cylinders should be placed on accurate scales so the chlorine can be weighed and the quantity used each day can be determined and reported. These scales should be so located that the cylinders will be cooler than the chlorinators, so the gaseous chlorine flowing from the cylinders to the chlorinator will not condense. The temperature in the room where the cylinders are located should not fall below 50°F or the chlorine liquid will not evaporate and the amount of gas obtained from the cylinder will be limited. In general, about 35 to 40 pounds can be obtained from each 100- or 150-pound cylinder at ordinary room temperature. If more than 35 pounds per day are required, then several cylinders can be connected together to obtain the desired quantity.

It is most important that precautions be taken to assure the continuous application of chlorine to the water to be treated. Special care should be exercised to prevent any equipment breakdown. For this reason, duplicate chlorinators should be provided so the standby chlorinator can be immediately used when needed. Spare parts, such as meter tubes, control valves, gaskets, etc., should also be kept on hand so repairs can be made readily. Duplicate auxiliary equipment, such as hydraulically or electrically driven pumps, etc., should also be available for immediate use.

The variety of gas chlorinators is too large to describe in detail here. The operator is referred to publications of manfacturers of such equipment for descriptions of chlorinators in which he is interested.

Hypochlorination

Other compounds of chlorine, such as sodium or calcium hypochlorite, also have disinfecting properties. Usually these hypochlorites are added to the water to be treated in solution form, although wells, tanks, cisterns, pipelines, etc. have been disinfected by adding the desired amount of powder directly to the water.

Sodium hypochlorite solution is marketed under a variety of trade names, and can be purchased in most communities. These solutions vary in strength from 3 to 15 percent available chlorine by weight and are reasonably stable when stored in cool, dark places.

Calcium hypochlorite is also used. There are several brands of calcium hypochlorite commercially available which contain from 65 to 75 percent chlorine by weight.

Hypochlorite solutions used in water works are diluted to a solution strength between 0.5 and 1 percent by weight. In preparing these solutions, the chlorine content of the concentrated solution must be taken into account. For example, if 30 gallons of 1 percent solution are to be prepared using sodium hypochlorite 14 percent available chlorine, the volume of sodium hypochlorite needed would be $\frac{30 \times 0.01}{0.14}$ or 2.14 gals. Expressed in another way, 2.14 gallons of 14 percent sodium hypochlorite would be diluted to 30 gallons with water to produce a 1 percent solution.

Though a hypochlorite solution may be added to a water supply by home-made devices, the usual type of equipment used is essentially a diaphragm solution pump manufactured by any one of a number of companies.

Manually controlled equipment is satisfactory when the water to be treated flows at a uniform rate, as in a pumped supply. When the rate of flow is not uniform, it is essential that a proportional feed hypochlorinator be used, generally of the meter-paced type. In all cases the capacity of the chlorination equipment should be sufficient to satisfy the chlorine demand and still leave an excess capacity for meeting any emergency. Duplicate installations are always desirable. Regardless of the type of equipment, it should be kept clean and should be in a relatively dry, accessible room.

The Practice of Chlorination

Natural waters represent complex solutions of many substances, most of which can be ignored, but some of which influence chlorination--at times, to a marked degree. Such factors are:

1. Suspended solids, which may shield bacteria from the destructive action of chlorine.

2. Organic matter, which reacts with chlorine so it no longer has disinfecting properties.

3. Ammonia, which reacts with free chlorine to form a chlorine compound having less effective disinfecting qualities than free chlorine itself.

4. The reaction of the water as measured by the pH value. Waters of low alkalinity and pH are most easily disinfected, i.e., waters with a pH of less than 7.2 when compared with waters having a pH above 7.6, such as prevail in the Great Lakes.

5. Nitrites, which react with and remove free chlorine, and which also may produce a false color when the orthotolidine (OT) test is used.

6. Manganese, which produces a false color when the OT test is used.

7. Iron, when present in concentrations of 1 ppm or greater, which causes an error in reading when the OT test is used. Iron and manganese when in the reduced state also react with chlorine and, hence, add to the amount of chlorine required for disinfecting purposes.

Rapidity of disinfection with chlorine is proportional to the temperature of the water, so that, other things being equal, chlorination is most effective with high water temperatures. On the other hand, chlorine is more stable in cold water and will remain in the cold water for a longer period of time. To an extent this compensates for the lower rate of disinfection in cold water.

Time available for the action of chlorine and the constitutents in the water is one of the most important aspects of chlorination practice. The minimum reaction period should be 10 to 15 minutes. Preferably, the reaction time should be several hours so effective disinfection may be assured without water reaching the consumer with an undesirable concentration of residual chlorine which may be objectionable due to the presence of tastes and odors.

If chlorination is to be successful:

1. The chlorine must be thoroughly mixed with all of the water to be treated.

2. Mixing must be continuous.

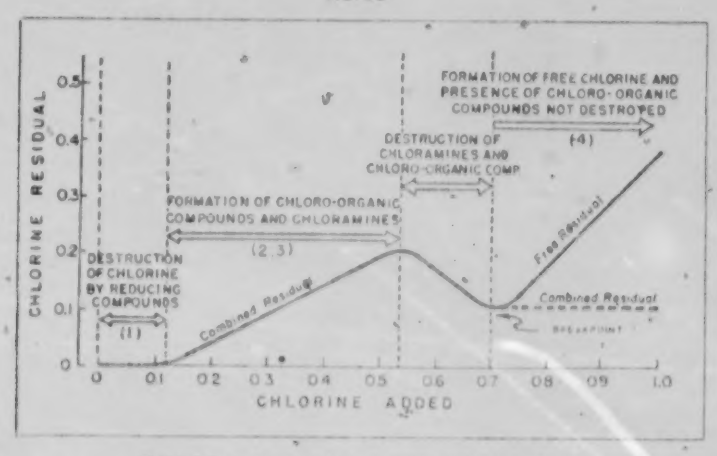
3. Enough chlorine must be added to accomplish the degree of treatment desired.

The proper mixing and continuity of application should be provided for in the design of the chlorination facilities. The quantity of "sufficient chlorine" varies with different water supplies and its determination is one of the prime duties of an operator.

Reaction of Chlorine in Water

Chlorine in water is a very active chemical agent. If a small amount is added, it will react with the many substances dissolved or suspended in the water and will then be destroyed as a disinfecting agent. Chlorine reacts rapidly with hydrogen sulfide, manganese, iron, and nitrites. These materials are called reducing compounds; their reaction with the chlorine results in no disinfection. If enough chlorine is added to complete the reaction with the reducing compounds, then a little more added chlorine will react with any organic matter to form chloroganic compounds. These have little or no disinfecting action and may cause tastes and odors. If enough chlorine is added to react with all the reducing compounds and organic matter, a little more chlorine will react with any ammonia which may be present to produce chloramines. The chloramines are weak disinfectants. For the effective destruction of bacteria with chloramines high concentrations and long contact times are required.

FIG. 62

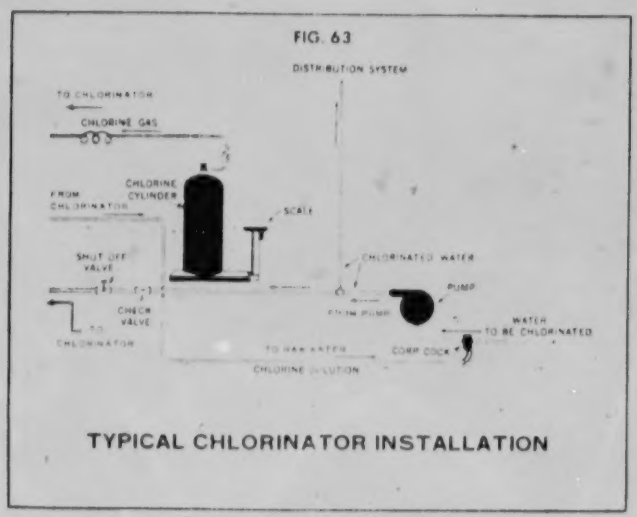


REACTIONS OF CHLORINE IN WATER

When the above reactions have been completed, any additional chlorine added will be present as free, available chlorine residual, a very active disinfecting agent. Figure 62 is a typical, graphic presentation of the reaction of chlorine and water, and such a curve is called the "chlorine demand curve".

The quantity of reducing substances, organic matter and ammonia varies with different waters and even varies from time to time in the same water supply. Consequently, the amount of chlorine that should be added to a water supply for disinfection also varies. The amount of chlorine used by the reducing substances and the organic matter is defined as the chlorine demand. Quan-

titatively defined, chlorine demand is equal to the amount of chlorine that is added minus the amount that is present after a reaction period (generally 10 minutes) as measured by the ortho-tolidine test. The amount of chlorine that remains after the selected reaction period is defined as residual chlorine and is expressed in parts per million (ppm). Residual chlorine can exist as chlorine compounds of ammonia, in which case it is called "combined available chlorine residual." It also can be present as free chlorine, in which case it is called "free available chlorine residual," or it can be present as both "combined" and "free available chlorine residual," in which case it is called "total available chlorine residual." In plant practice free residual chlorine should be maintained in the treated water.



TYPICAL CHLORINATOR INSTALLATION

Factors Influencing Chlorination

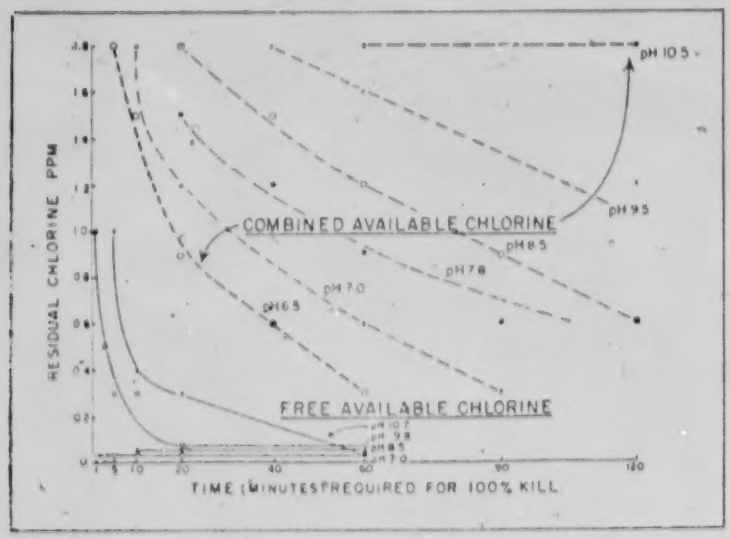
Listed below are the important factors that influence the desired chlorine residual:

1. Time-Concentration. These two mutually related factors take into consideration the period of reaction time available for disinfection, and the quantity and kind of chlorine residual. If reliance is to be placed on combined available chlorine, which is a weak disinfectant, a greater concentration acting over a longer period of time must be provided. On the other hand, if free available chlorine residual, an active disinfectant, is to be maintained, the reaction period can be correspond-

ingly less. Experience has shown that a free available chlorine residual of 0.05 ppm with a reaction period of 10 minutes at a pH of 7.0 will result in the same bacterial kill as a combined available chlorine residual of 0.6 ppm with a reaction time of 60 minutes. When the reaction time between the point of application and the consumption of water is short, say about five minutes, only a free available chlorine residual will give effective disinfection. Figure 64 illustrates this point.

2. Temperature. The temperature of the water markedly affects the disinfecting action of residual available chlorine. At lower temperatures, bacterial kill tends to be slower and higher residual concentrations are needed. The effect of low temperatures is greater with combined residual chlorine than with free chlorine residual. This is shown on figure 65.

FIG. 64

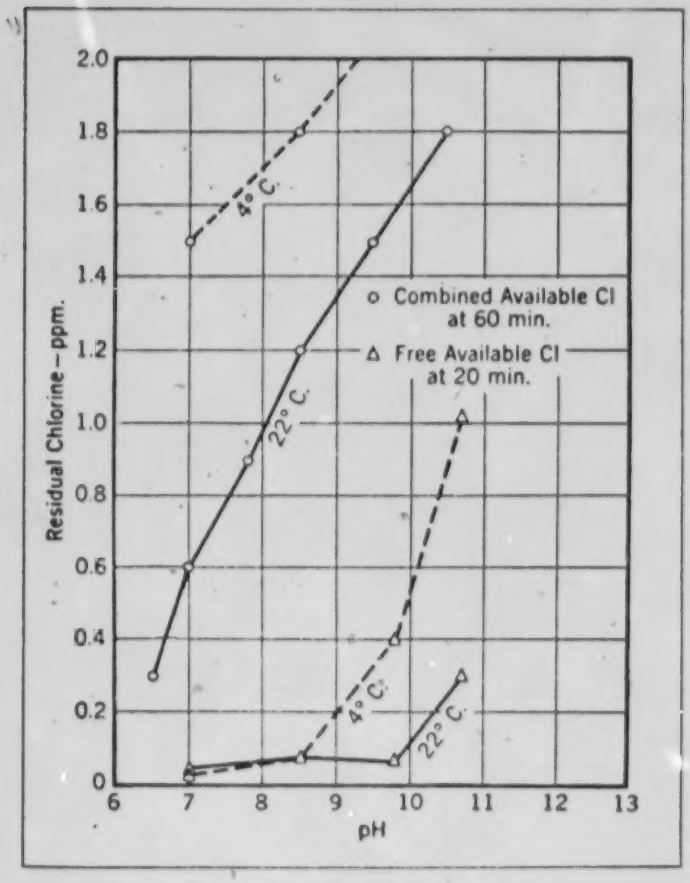


EFFECT OF TYPE OF RESIDUAL, AND TIME

62

3. pH. As stated previously, the pH of the water affects the disinfecting action of chlorine, particularly combined available chlorine residual. At pH 6.5 and a temperature of 70° F., 0.3 ppm of combined residual causes a 100 percent bacterial kill. With the same temperature, at pH 7.0 the combined residual must be increased to 0.6 ppm, and at pH 8.5 it must be increased further to 1.2 ppm to accomplish the same degree of bacterial kill. Data for other conditions of temperature and pH, as well as for free available chlorine residuals is also shown in Figure 65.

FIG. 65



EFFECT OF TEMPERATURE
ON RESIDUAL CHLORINE

Chlorination Techniques

Extended use of chlorine in water treatment practice has led to the development of specific terms describing the process.

When chlorine is applied to a water supply before other treatment processes, such as coagulation, etc., the practice is called "pre-chlorination." Conversely, when chlorine is applied after a treatment process, such as filtration, the practice is called "post-chlorination."

Application of chlorine dosages greatly in excess of those required for disinfection is called "super-chlorination." Deliberate treatment of the water to remove residual chlorine is called "de-chlorination." Generally, "super-chlorination" is followed by "de-chlorination" in order to maintain a desired residual. Materials used for dechlorination are sulfur dioxide, sodium bisulfite, sodium sulfite, sodium thiosulfate, and activated carbon. As a result of super-chlorination a "break" may be produced in the chlorine demand curve. Under this circumstance, this practice is referred to as "breakpoint" chlorination (Figure 62).

With the development of the orthotolidine-arsenite test the practice of "free residual" chlorination has come into wide use. This practice consists of adding enough chlorine so that a residual consisting almost entirely of free available chlorine results. The orthotolidine-arsenite (OTA) test is used in this instance as the laboratory control aid which distinguishes and measures quantitatively the combined and the free available chlorine residuals. The actual laboratory procedure will be discussed in the chapter on "Laboratory Procedure."

Advantages of Free Residual Chlorination

Because of its many advantages, including ease of control, the practice of free residual chlorination is generally used.

The advantages of free residual chlorination are:

1. Effective disinfection can be obtained with a contact period of 10 minutes, whereas combined chlorine residual requires at least 60 minutes.

2. No change in chlorine residual is required with a change in pH between 6.0 and 8.0, while combined residual must be changed with increasing pH.

3. No marked change in chlorine residual is required with a change in temperature, while combined chlorine residual must be increased markedly with a decrease in temperature.

4. With many waters, there is a distinct improvement of tastes and odors if the combined chlorine residual is replaced by free residual chlorination.

5. After a free chlorine residual has been carried throughout a distribution system, it is persistent and can be maintained.

Both the concentration of free, and the concentration of combined chlorine residual are of importance when practicing free residual chlorination. When practicing free residual chlorination it is recommended that at least 85 percent of the total chlorine residuals be in the free state.

By utilizing the above principles as a guide, and allowing for a factor of safety, the following table has been prepared to indicate the desirable minimum concentration of free chlorine residual after a disinfecting period of 10 minutes as compared with the desirable minimum concentration of combined chlorine residual after a disinfecting period of 60 minutes at the specified pH values:

Recommended Minimum Concentrations of Free Chlorine Residual

versus

Combined Chlorine Residual to Insure Effective Disinfection

pH Value	Minimum Concentration of FREE Chlorine Residual, Disinfecting Period at Least 10 Minutes	Minimum Concentration of COMBINED Chlorine Residual, Disinfecting Period at Least 60 Minutes
6.0	0.2	1.0
7.0	0.2	1.5
8.0	0.4	1.8
9.0	0.8	Not applicable
10.0	0.8	Not applicable

Chlorine Hazards

Chlorine gas is extremely toxic and corrosive in moist atmospheres. Dry chlorine gas can be handled safely in steel containers and piping, but with moisture must be handled in corrosion-resisting materials such as silver, glass, rubber and certain plastics. The gas is highly irritating to mucous membranes and a very small percentage in air causes severe coughing. Heavy

exposure can be fatal. Thus, it is important that one or more of several types of gas masks be provided and that persons handling chlorine be properly instructed in safety procedures and be constantly alert for leakage. The chlorine gas mask should be properly stored and ready for instant use at a convenient location outside of the chlorinator room.

Operation and Maintenance of Chlorinators

Types of Equipment	Remarks
1. Dry (direct) feed gas chlorinators	Application of dry chlorine gas to the water. Used only where water under pressure is not available; care in selecting point of application is required.
2. Solution feed gas chlorinators	Solution feed chlorine gas mixed with auxiliary supply of water and solution applied to water to be treated. Vacuum chlorinators of this type are preferable.
3. Electrolytic cell gas chlorinator	Generation of chlorine at point of use. For special applications. Of little value in water works practice.
4. Hypochlorinators-chlorine compounds	For relatively low flows, or for intermittent, steady, or emergency use. May be electric or water meter driven; or by gravity or displacement.

All chlorinators should be installed for continuous trouble free operation. Chlorine gas will dissolve in water to form a solution having a maximum concentration of 0.3 per cent or 3,000 mg/l.

Types of Control for Chlorinators

1. Manual	Rate of feed varied by hand. Only suitable at points where flow of water to be treated is constant or flow is varied by hand at which time of feed can be set.
2. Semi-automatic	Feed started or stopped automatically by electric or hydraulic means.

3. Fully automatic — Flow meter control with proportional displacement.

Selection of Point of Chlorination should be based on:

1. Moderate pressure at point of chlorination.
2. Minimum variation in flow rates (chlorinator capacity and range).
3. Best facilities for securing rapid and thorough dispersion of chlorine throughout water treated.
4. Accessibility of chlorination equipment for inspection.
5. Minimum damage caused by high chlorine residuals.
6. Availability of suitably heated building, water supply and cylinder storage.
7. Available electrical power and auxiliary power.

Installation Features of Importance

1. Chlorinators should be located near point of application.
2. Chlorinators should be in a separate room, above ground if possible.
3. Ample working space around equipment and storage space for spare parts should be provided.
4. An ample supply of water under pressure of at least 15 pounds per square inch and three times as much back pressure at point of treatment is required. Booster pumps may be necessary. In general, a minimum of 40 to 50 gallons per day is required per pound of chlorinator capacity. Failure of water supply means failure of chlorination. The supply must be clear enough not to clog strainers. Minimum water pressure should be 10 to 15 psi.
5. The building should be adequately heated. The chlorinator temperature should be above 50°F to avoid clogging by chlorine ice. Chlorine cylinders must be kept at a reasonable temperature and chlorine piping and chlorinator must be at a higher temperature to prevent the condensation of gas into liquid in pipe lines and chlorinator. The maximum temperature at which a chlorine cylinder is stored should not exceed 140°F.

6. It is not advisable to draw more than 40 pounds of chlorine from any one cylinder in a 24-hour period because of the danger of "freezing" and slowing the chlorine flow. If more chlorine is necessary, two or more tanks should be connected and used in parallel. With ton cylinders, the chlorine gas limit is about 400 pounds per day.

7. Adequate light should be provided.

8. Adequate and continuous ventilation is desirable to remove leaking chlorine gas. Forced ventilation must be provided to remove gas if large leak develops. Inlet of forced ventilation system must be near floor.

9. Provisions for convenient handling and storage of chlorine containers are important. It can be dangerous and expensive to move cylinders up and downstairs and through narrow doors or passageways.

10. Facilities for the adequate measuring and controlling of chlorine dosage are required. Scales and loss-in-weight recorders are desirable as a continuous check on, and as a record of, chlorination continuity.

Continuity of Chlorination

When chlorination is practiced for disinfection, it is needed continuously. Therefore, arrange that chlorination will function for 1,440 minutes or 86,400 seconds per day. To provide continuous chlorination the chlorine gas lines from cylinders should feed to a manifold so cylinders can be removed without interrupting the feed of gas. It is necessary to provide duplicate units or an emergency hypochlorinator, an adequate supply of spare parts, and an adequate number of cylinders connected to the manifold to supply gas at the maximum rate of feed. The maximum amount of chlorine feed for a 100 or 150 pound-cylinder should never be greater than at a rate of 35 pounds per day.

Chlorine Containers

1. Notes on their capacity, handling and storage:

   - Cylinders are available in 100-lb; 150-lb; and 1-ton sizes.
   - Tank cars contain 16, 30 or 55 tons.
   - Cylinders are provided with fusible plugs which melt at 157 to 162°F.

- Cylinders will not explode during handling and may be handled with complete safety.

- Cylinders are provided with draw off valve protective caps.

- Cylinder pressure varies directly with temperature (40°F. to 150°F.).

- Liquid chlorine fills only about 80 per cent of cylinder capacity as a safety measure.

- Cylinders can be rolled in a vertical position. Where large cylinders are used, a lifting device such as a block and tackle is desirable.

- Protective cap should always be replaced when moving cylinder.

- Cylinders should be stored at temperatures above 50°F but kept away from steam pipes, radiators and other direct heat sources.

- Small cylinders should be stored upright but ton containers may be stored horizontally.

Safety precautions.

1. Keep cylinders away from excessive heat.

2. Handle so there will be no danger of their falling.

3. Follow manufacturer's instructions on care and operation of valves.

4. Repair leaks at once; locate by ammonia, not smell.

5. Keep gas mask available for prompt use.

6. Have first-aid equipment available and be sure personnel are properly instructed in aiding persons overcome by gas.

First-Aid in Case of Chlorine Inhalation

1. Remove patient to a place where the air is warm and fresh.

2. Keep patient quiet and warm.

3. Do not give alcohol.

4. If patient is conscious, give black coffee or essence of peppermint.

5. Warm milk or cream will relieve throat irritation.

6. Steam inhalations containing tincture of benzoin compound help relieve coughing and breathing difficulty.

7. When patient is not breathing, give artificial respiration.

8. Do not use Pulmotor or other mechanical means of resuscitation.

9. Call or consult physician. In case of serious exposure, the patient should be taken to a hospital.

CHLORINATION OF SMALLER WATER SUPPLIES*

Chlorination is one of the most important processes used in preparing water for domestic use. This is particularly true in the case of many smaller supplies where chlorination may be the only treatment given the water. If the raw water is of reasonably good quality - physically, chemically, and bacteriologically - chlorine alone can produce a potable water.

The practice of chlorinating public water supplies, begun in this country in 1908, together with other refinements in treatment, has caused the incidence of water-borne diseases to decline steadily. In order to maintain this record of protecting public health, constant vigilance is needed to safeguard water supplies and assure continuity of adequate treatment. Manufacturers have developed chlorination and control equipment which can be reliably depended on to provide such continuity of operation on a 24-hour-a-day basis; however, this equipment is no better than the person who operates it. Good operation implies a knowledge of how to operate and maintain the equipment as well as a knowledge of how to properly apply chlorine to produce the desired results. Stand-by units are desirable to assure the continuity of disinfection upon which the safety of supplies depends.

There are many factors which affect chlorination practices. It is the aim of this paper to discuss some of these points and to describe methods used in applying this chemical to smaller size public water supplies. Adequate knowledge will help to assure satisfactory results.

WHAT IS THE MAIN PURPOSE OF CHLORINATION OF WATER SUPPLIES?

The prime reason for adding chlorine to a water supply is to disinfect the water and, thus, make it safe for drinking and other domestic use. The term "disinfection" means that sufficient chlorine is present in the water for a long enough time to kill the bacteria present, including all the disease producing organisms. This term is used to distinguish the practice from "sterilization", which implies that all living organisms are destroyed. In treating water supplies the chlorine concentrations and contact times used are designed to disinfect the water, not sterilize it. In water purification practice the term "chlorination" has largely replaced the term "disinfection".

*Source: James E. Rosencrance, Sanitary Chemist, Division of Sanitary Engineering, West Virginia State Health Department.

ARE THERE OTHER BENEFITS TO BE DERIVED FROM CHLORINATION OF WATER?

Chlorine added to water will help in the control of tastes and odors. Chlorine is also used for removal of ammonia, iron, manganese, and hydrogen sulfide. It can help prevent red water difficulties. It inhibits organic growths in mains and filters and helps in slime and algae control. In many cases it is of benefit in water coagulation, particularly where color removal is desired.

WHERE SHOULD CHLORINE BE APPLIED?

Application points are chosen according to the purpose for which chlorine is added and the physical layout of the plant or system. The term in which we are most interested is plain chlorination, which refers to chlorination where no other treatment is involved. This use applies to many small supplies.

WHERE IS THE BEST POINT TO APPLY CHLORINE IN A SMALL GRAVITY SUPPLY?

As a general rule, the best application point for raw water chlorination is as close to the source of water as possible.

WHERE IS THE BEST POINT TO APPLY CHLORINE IN A SMALL WELL SUPPLY?

If the type of pump and well construction permits, the chlorine may be applied down in the well near the point of intake. If application cannot be made down the well, for physical or other reasons, the chlorine may be applied in the pump discharge. If pressure or gravity sand filters are used, the chlorine is generally applied ahead of the filters. If diatomaceous earth filters are used, it may be desirable to add chlorine after the filters.

WHAT OTHER CONSIDERATIONS SHOULD BE MADE IN SELECTING THE POINT OF APPLICATION?

Chlorine should be applied uniformly to all portions of the water being treated. This implies good mixing at the point of application. The chlorine should be applied far enough up stream from the first consumer to permit it to act and, also, to insure that the first consumer does not receive an undesirable high concentration of chlorine. To accomplish this, chlorine dosage should be carefully regulated, and a minimum of 30 minutes should elapse between the point of application and the first consumer.

IS ALL THE CHLORINE ADDED TO WATER AVAILABLE FOR DISINFECTION?

Chlorine reacts with other substances in water, and the amount

used up in this fashion is not available for disinfection. The organic matter present will react with the chlorine to form chloro-organic compounds, which reduce the effective dosage of the disinfecting chemical. Chlorine also reacts with any ammonia present to form chloramines. These chloramines are disinfectants but are slower acting than the chlorine itself. Chlorine also reacts with iron and manganese, which is present in the reduced state, and with nitrates. All of these reactions serve to reduce the amount of chlorine available for disinfection.

ARE THERE OTHER FACTORS WHICH MAY INFLUENCE THE DISINFECTION POWERS OF CHLORINE?

Water temperature and pH affect the rapidity with which chlorine acts to disinfect. As the temperature increases, the activity of the chlorine, also, increases; therefore, in cold water either the concentration of chlorine or the contact time must be increased to obtain the same disinfection action that would be obtained in a warmer water. This phenomenon is more pronounced with combined chlorine residuals than with free residuals. With combined residuals, in order to obtain the same disinfection action at 40°F as at 70°F the chlorine concentration must be more than doubled. As the pH increases, the disinfection action of chlorine decreases, particularly with combined residuals. It is easier to disinfect a low alkalinity water than a high alkalinity water. At pH 6.5 approximately one-half the concentration of combined residual chlorine will produce the same degree of disinfection as that produced at pH 8.0. This means that where combined residuals are used in cold or high pH water either the concentration of chlorine or contact time must be increased. The effectiveness of free residuals is not affected by temperature changes or changes in pH between 6.0 and 8.0.

ARE THERE CONDITIONS WHERE CHLORINATION ALONE WILL NOT MAKE A WATER SAFE?

If the average bacterial population of the raw water is above an MPN of 50 per 100 ml, it may not be safe to rely on chlorination alone to make the water safe. Raw water storage, filtration, and post-chlorination practices should then be used to assure the safety of the water. Similarly, in water that is high in turbidity or suspended solids, the bacteria may be shielded from the action of the chlorine. If water of this nature is being handled, other treatment means should be provided to improve its quality. This will enable the chlorine to disinfect the "polished" water effectively.

WHAT ASSURANCE IS THERE THAT CHLORINATION RESULTS IN EFFECTIVE DISINFECTION OF WATER?

The standard coliform test can be used to check the purity of the

water. If coliforms are absent, the chlorine has done a satisfactory disinfecting job; however, the coliform test is a "post mortem" one since the water represented by the sample being examined has normally been consumed before the results of the test are known. The coliform test serves as a check on the effectiveness of chlorination. Results over a period of weeks or months are a good indication of the overall efficiency of a treatment program. Chlorine residual tests must be relied on to provide an immediate check on the adequacy of chlorination. More rapid methods of bacterial examination are now available through the use of membrane filter techniques.

WHAT METHODS ARE USED FOR ADDING CHLORINE TO WATER?

A chlorinator or hypochlorinator is used to accurately measure and feed chlorine to the water. A solution-type chlorinator takes chlorine gas from cylinders or containers, mixes it with water to form a chlorine solution, and then applies this solution to the water. The units provide some means for controlling and measuring the amount of chlorine fed.

Hypochlorinators feed a solution of sodium hypochlorite or calcium hypochlorite to the water. Sodium hypochlorite is available commercially as a liquid containing from about 3 to 15 per cent chlorine. This concentrated solution is diluted with water before use. Calcium hypochlorite is available as a 35 per cent or 70 per cent powder which is prepared for use by dissolving it in water.

WHAT DETERMINES THE TYPE OF CHLORINATION EQUIPMENT TO BE USED?

The quantity of water to be treated and, thus, the amount of chlorine to be fed helps determine the type of equipment to be used. Generally, gas equipment is used for treating large quantities of water, and hypochlorinators are used for smaller supplies.

WHAT UTILITIES ARE NEEDED FOR A CHLORINATOR INSTALLATION?

Hypochlorinators are electrically operated or water operated. The utilities required for this equipment include: electricity; drain; water tap to supply water for making solution; and enough heat to keep the building above freezing during the cold months.

Gas equipment requires adequate water pressure to operate the chlorinator, electricity, heat, ventilation, and floor drains, plus whatever accessories are necessary to complete the installation. Adequate gas mask equipment must be provided.

THE CHLORINATION THEORY

The reaction mechanisms involved in the addition of chlorine to water appear to be very simple. In reality, however, this is not at all the case. First, waters to which chlorine is added are not simply H_2O but are, in fact, extremely complex solutions of many elements and their compounds, including varying amounts of numerous organic substances of animal, vegetable, and synthetic origin. Secondly, the reaction does not yield a simple addition compound of Cl_2 and H_2O.

When chlorine (a solution of chlorine gas or hypochlorite) is added to water - reducing the reaction to its most elementary form - a mixture of hypochlorous acid (HOCl) and hydrochloric acid (HCl) is formed:

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

The hypochlorous acid ionized or dissociates into hydrogen and hypochlorite ions:

$$HOCl \longrightarrow H^+ + OCl^-$$

Both reactions are dependent upon the pH value of the water. Between pH 6.0 and 8.5 there occurs a very sharp change from undissociated to completely dissociated hypochlorous acid. Chlorine exists predominately as HOCl at low pH levels; above pH 7.5 hypochlorite ions (OCl^-) predominate, while above pH 9.5 chlorine exists almost entirely as OCl^-.

CHLORINE'S ACTION ON BACTERIA AND OTHER ORGANISMS.

Although chlorine as a chemical oxidant has considerable utility in water treatment processes its primary use for disinfection is by far the most important.

Several theories have been advanced to explain the mechanism of bacterial destruction or inactivation by chlorine. The current belief is that death results from the action of chlorine on essential bacterial enzymes. According to theory, hypochlorous acid (HOCl) exhibits greater ability to penetrate the cell membrane and to oxidize the essential enzyme(s) than hypochlorite (OCl^-) and other chlorine forms.

ANALYTICAL DETERMINATIONS

Complete and specific directions for the determination of residual chlorine are given in Standard Methods for the Examination of Water and Sewage. This section thoroughly discusses all phases of the tests, including preparation of reagents, equipment

and apparatus, precautions, and procedures. The following are briefed forms of those directions.

DPD TEST FOR CHLORINE RESIDUAL

Note: The following discussion of the Hach DPD Chlorine Test Kit is not to be taken as an endorsement of this particular kit by either the Division of Sanitary Engineering, State Department of Health, or the State Department of Education. Regardless which DPD kit you use, you are urged to follow the manufacturer's directions in order to obtain accurate results.

Procedure - Free Chlorine - Fill one tube to the ring (5 ml.) with clear water and place it in the left-hand opening of the comparator (behind the color disc). Fill the other tube to the 5 ml. mark with sample water. Add the contents of one DPD Free Chlorine Reagent Powder pillow to the test sample. Swirl to mix and place it in the right-hand opening of the comparator. It is not necessary that all of the powder be dissolved. Hold the comparator up to light such as a window, the sky, or a lamp, and view through the openings in the front. Rotate the disc until a color match is obtained. Read the mg/l free chlorine (Cl_2) within one minute through the scale window.

Total Chlorine - Follow the same procedure as above for free chlorine residual, but use one of the pillows from the box marked "DPD Total Chlorine Reagent," and let the sample stand for three minutes before using the comparator for a color match. Again, not all of the powder must disolve in order to get accurate readings.

Interferences - If high concentrations of monochloramine (combined chlorine) are present, they may interfere with the free chlorine test after one minute developing time. Bromine, iodine, ozone, and oxidized forms of manganese may also react and read as chlorine.

Caution: Do not leave the color disc where it will be exposed to direct sunlight. The color on the disc will fade and faulty readings will result.

Known suppliers of DPD field test kits which are approved by the State Department of Health are listed below. Other suppliers offering kits of equal quality to those listed should also be considered, but approval of kits not listed should be obtained from the State Department of Health before purchase by your utility. The kits cost $20.00 to $35.00 each. The DPD-pH kits cost approximately $50.00 each.

Hach Chemical Company
P. O. Box 907
Ames, Iowa 50010
Telephone: (515) 232-2533 or
1-800-247-3986 (toll free)

(Free and Total Chlorine Test Kit; Model CN-66, Cat.#2231-01; Free, Total Chlorine and pH Test Kit, Model CN-67, Cat.#14111-00)

Taylor Chemicals Company
7300 York Road
Baltimore, Maryland 21204
Telephone: (301) 823-1573

(Model 1234 DPD Midget Tester; Model 1259 DPD Test Kit; Model 1244 DPD-pH Test Kit)

LaMotte Chemical Products Company
Chestertown, Maryland 21620
Telephone: (301) 778-3100

(Model LP-18, Code 6991, DPD Chlorine "Octet" Comparator Kit; Model LP-8, Code 6980, DPD-pH Test Kit)

ADDENDUM

DOES THE CHLORINATION OF PUBLIC WATER SUPPLIES PRESENT ANY HAZARD TO HUMAN HEALTH?

Chloroform and other trihalogenated methanes have been detected in municipal water supplies in this country and abroad as a result of chlorinated processes during water treatment. The highest concentrations of these compounds were found in finished waters having surface waters as their source. These trihalogenated compounds resulting from chlorination are not an acute hazard to man at the levels detected, but their presence suggests the need to monitor finished waters for these and other organohalogens and to determine whether there may be chronic effects.

As a result of these recent findings, the National Environmental Protection Agency research scientists have embarked upon an extensive study of public water supply systems in this country to determine factually whether there is any basis or need to restrict the use of chlorine in water treatment.

The public should not be unduly alarmed to the point that they avoid or stop using chlorinated water. The vast benefits of chlorine in water treatment in preventing disease are well established. The level of health risk from these chlorinated organics must be based on comprehensive and conclusive research not only from water but also from other sources and exposures.

Revised January 1975
WSS/JER/DCB/lm

CHLORINATION EQUIPMENT -- OPERATION AND MAINTENANCE*

Objective

Equipment utilized for chlorination of water supplies is specifically designed to feed continuously and accurately the desired amount of chlorine or chlorine compound. Such equipment is called a chlorinator or chlorine feeder. The term chlorinator usually refers to equipment for feeding chlorine gas; hypochlorinator refers to equipment for feeding hypochlorites.

Continuous chlorination of all water supplies can be accomplished only when feeding equipment is kept in constant operation. The operator must, therefore, have sufficient knowledge to operate the available equipment and maintain it properly. This expertise may involve rapid repair or replacement of defective parts. Information about various types of chlorine feeders follows.

Hypochlorinators

Hypochlorinators are machines specifically designed to consistently and accurately feed hypochlorites to water.

As mentioned in Chapter V, the hypochlorite compounds most frequently used are sodium hypochlorite and calcium hypochlorites. Since sodium hypochlorite is supplied only in solution, a solution feeder is required for its application. Calcium hypochlorites are supplied in dry, granular or pellet form, which can be fed through dry-chemical feeders, but they are seldom so applied. Use of calcium hypochlorite pellets is also rather rare in water plants. For these reasons, only solution feeding of hypochlorites will be discussed.

Calcium Hypochlorite Solutions

Calcium hypochlorite is readily soluble in either warm or cold water, and very strong (concentrated) solutions can therefore be prepared. It reacts with water in the same manner as does chlorine gas to produce a solution of hydrochloric and hypochlorous acids, a highly corrosive solution. Therefore, the solution container must be made of corrosion-resistant material. Wood, ceramic, glass, plastic, or rubber-lined steel containers are suitable.

*Source: Basic Water Treatment Operator's Manual, No. M18, American Water Works Association, 2 Park Avenue, New York, N. Y. 10016, 1971. pp. 49-58.

All hypochlorite solutions can cause skin burning and destroy clothing. When handling these solutions, such protective apparel as rubber gloves, rubber aprons, and goggles should be worn. Avoid splashing the solution. Accidental splashes of solution on the operator should be treated immediately by thoroughly washing all exposed parts of the body with ample quantities of water. Clothing also should be thoroughly washed before reuse.

In preparing the calcium hypochlorite solution, the operator should follow instructions furnished by the equipment manufacturer as to amounts of water and hypochlorite to be used. Usually a solution containing 1-2 per cent of available chlorine is prepared. This solution should be prepared in a separate container and permitted to stand for 8-24 hr before actual use to facilitate removal of insoluble compounds. The clear solution should then be siphoned or poured into the container supplying the feeder. A 24-hr supply of solution is usually prepared. This procedure usually requires at least two containers.

Calculations for Calcium Hypochlorites

In some plants, records are kept of the number of pounds of dry hypochlorite used over a 24-hr period, and these records are then used to calculate the chlorine dosage in ppm. Thus, the dosage is the number of pounds of available chlorine added to each million pounds of water. The method of calculation is illustrated in the following example:

> What is the chlorine dosage when 30 lb. of 70 per cent HTH (a calcium hypochlorite compound) is used to treat 300,000 gal of water?
>
> By 70 per cent is meant that each 100 lb of HTH contains 70 lb of available chlorine. This percentage must be divided by 100 to obtain the pounds of available chlorine in each pound of HTH; in the case 0.7 lb chlorine/lb of HTH. Thus 30 x 0.7 = 21 lb of chlorine used. 300,000 gal of water equals 300,000/1,000,000 = 0.3 mil gal. Thus, the chlorine used per mil gal is 21 ÷ 0.3 = 70 lb. Since 1 ppm equals 8.3 lb/mil gal, 70 must be divided by 8.3 to obtain the ppm dosage figure. Thus, 70 ÷ 8.3 = 8.4 ppm, the chlorine dose in this example.

Hypochlorite solutions are often made up as 1 or 2 per cent available chlorine solutions. A 1 per cent solution of chlorine can be taken as containing 0.08 lb/1 gal solution of chlorine. A 2 per cent solution contains 0.16 lb/gal chlorine. A 2 per cent chlorine solution can be prepared by dissolving 4 oz HTH/gal of water. This calculation is exact enough for practical purposes.

A 1.7 per cent HTH solution (2.5 oz HTH/gal of water) produces a chlorine solution each gallon of which has a strength of 0.10 lb of chlorine. Such a concentration simplifies record keeping. Example:

Assume that 15 gal of such a 1.7 per cent HTH solutionare used to treat 750,000 gal of water. What is the chlorine dose in lb/mil gal and in ppm?

Solution:

1). The amount of 1.7 per cent HTH solution used per mil gal of water is 15/750,000 x 1,000,000 = 20 gal.

2). 20 gal of this HTH solution contains 20 x 0.1 = 2 lb of chlorine. The chlorine dose is 2 lb/mil gal.

3). A ppm is equal to 8.3 lb/mil gal. Thus, the parts per million of chlorine in this problem is 2 ÷ 8.3 = 0.24 ppm.

High-test calcium hypochlorite compounds will retain their chlorine content for many months when properly stored in cool areas. Loss of chlorine can occur, however, once a container is opened, particularly if the contents are exposed to moisture in the air. If exposed hypochlorite is used, more material may be required to obtain the desired chlorine concentrations.

Preparing Sodium Hypochlorite Solution

Sodium hypochlorite is supplied only in solution form containing 5-17 per cent available chlorine. Being in solution form, it is ready for use as delivered. The delivered solution concentration of chlorine is, however, usually too high for use in hypochlorinators and must be diluted with water. The same precautions used in handling solutions of calcium hypochlorite should be used with sodium hypochlorite solutions. All containers also must be corrosion-resistant. Instructions in the equipment manufacturer's manual should be closely followed.

Unlike calcium hypochlorite, no sediment problems occur with sodium hypochlorite solutions, and this chemical can be diluted in the container that supplies the feeder. Two containers are desirable so that any errors in dilution can be corrected before the solution is drawn into the feeder.

Calculations for Sodium Hypochlorite

1. It is essential to know how much water and sodium hypochlorite solution must be used to obtain a desired concentration of chlorine in the solution going to the feeder. This information is obtained with the following equation:

$$\text{Gallons of concentrated solution} = \frac{\text{Gallons of dilute solution} \times \text{Diluted \%}}{\text{\% of concentrated solution}}$$

As an example, how many gallons of 15 per cent sodium hypochlorite solution are required to prepare 55 gal of 2 per cent solution? The equation becomes 55 x 2/15 = 7.33 gal.

Therefore, a mixture of 7 1/3 gal of a 15 per cent sodium hypochlorite solution and 47 2/3 gal of water will give 55 gal of solution containing 2 per cent available chlorine.

2. The following equations may be used for either calcium- or sodium-hypochlorite solutions. The first is used for calculating the chlorine dosage.

$$\text{Chlorine dosage(ppm)} = \frac{\text{Gallons of solution} \times \% \text{ chlorine} \times 10{,}000}{\text{Gallons of water treated.}}$$

For example, what is the chlorine dosage when 40 gal of a 1.5 per cent chlorine solution are used to treat 500,000 gal of water? The equation becomes

$$\text{Chlorine dosage(ppm)} = 40 \times 1.5 \times 10{,}000/500{,}000 = 1.2 \text{ ppm.}$$

3. To determine the quantity of solution required to treat a certain amount of water, the following equation is used:

$$\text{Gal of solution} = \frac{\text{Desired dosage(ppm)} \times \text{Gallons water treated}}{\% \text{ chlorine} \times 10{,}000}$$

For example, how many gallons of a 1 per cent solution are needed to treat 200,000 gal of water to obtain a dosage of 0.8 ppm? The equation becomes

$$\frac{0.8 \times 200{,}000}{1 \times 10{,}000} = 16 \text{ gal.}$$

Sodium hypochlorite solutions will gradually lose strength during storage. Storage for 100 days can result in 50 per cent loss in strength. For this reason sodium hypochlorite storage should be limited to about one month or six weeks.

Metering Flow

Once the hypochlorite solution of the desired chlorine concentration has been prepared, means must be available to feed it accurately in proper amounts. This may mean a few gallons or as many as 500-1,000 gpd. Many equipment manufacturers offer hypochlorinators to meet this wide range of requirements. Naturally, these feeders are offered in different sizes to meet specific needs. For example, feeding capacities range from 0-20, 0-60, and 30-1,000 gpd.

To meet the varying conditions that may exist in chlorination of water supplies, hypochlorinators that are powered by water pressure, electric power, compressed air, or gasoline engines can be obtained.

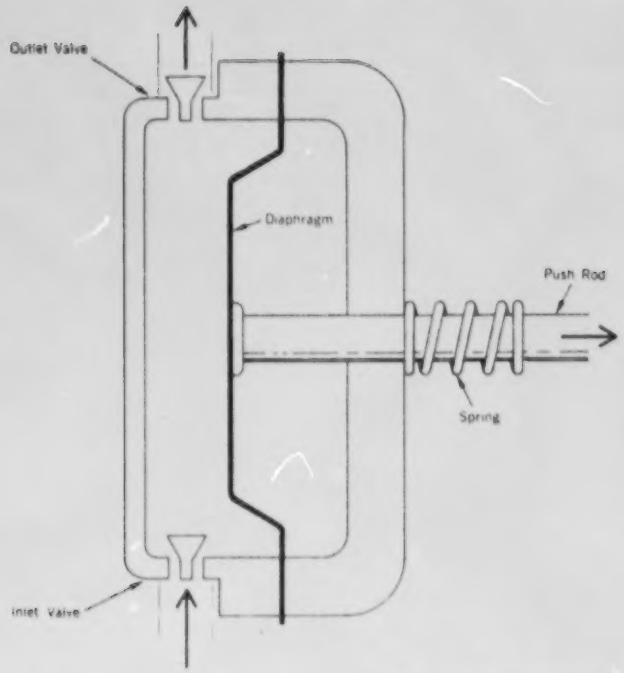


Fig. 6.1. The Diaphragm Principle in a Positive-Displacement Hypochlorinator

Although other methods of metering are employed in various hypochlorinators, discussion here will be limited to the so-called positive-displacement-type feeders. Stated very simply, they suck specific amounts of solution into containers and then expel the same amounts to the points of chlorine application. Most feeders of this type use the diaphragm principle (Fig. 6.1).

The amount of solution that is fed can be regulated by the length of stroke of the push rod. If the diaphragm moves only a short distance, small amounts of solution will be sucked into the feeder. Longer strokes will feed more solution. Many hypochlorinators permit regulation of the length of stroke merely by turning a control knob on the machine, even while the equipment is in operation.

Most hypochlorinators also provide means for regulating amounts of solution by changing the number of strokes over a period of time, sometimes from as low as four to more than 60 strokes per minute. Alterations in stroke rate are usually made by changing belts or gears.

Hypochlorinator design can differ considerably between manufacturers. Manufacturers' instruction bulletins should be consulted for specific models.

One type of diaphragm unit is termed a single, or simplex head feeder. When very large amounts of hypochlorite solutions must be fed, units with more than one head can be supplied. A

hypochlorinator with two heads (dual head or duplex) will permit the feeding of twice as much solution. Triple-head units are also available. The term "head" can apply to other diaphragm plunger-type feeders.

The simplest type of hypochlorinator is designed for manual feed-rate adjustment. Feed rate changes are accomplished by turning a knob or changing belts or gears. More sophisticated units can be operated automatically to the extent of changing feed rates to conform to amounts of water passing through plants.

Maintenance of Hypochlorinators

No hypochlorinator is so automatic or mechanically refined that no maintenance is required. Even the best feeders must be cleaned and serviced regularly to ensure efficient and continuous operation. Furthermore, unless an alarm system is incorporated to give warning of interruption of feeding, the supply of hypochlorite solution must be checked periodically and replenished when necessary.

Clogging at points where solution flow is restricted is the most frequent cause of feeding problems. Clogging is much more likely to develop when calcium (as opposed to sodium) hypochlorite solutions are being used. Points involved may be orifices and valves. Deposits at such points can be aggravated if the water contains appreciable amounts of calcium or magnesium hardness, or iron. Problems will develop less frequently if a program is adopted to flush daily all vital parts. Also, a strainer should be installed on the end of the tubing that extends into the hypochlorite solution. This strainer should be flushed and cleaned with a brush once each day, or as dictated by experience.

At least once every six months, hypochlorinators should be taken apart for inspection. Deposits should be removed by brushing and rinsing. For stubborn deposits a 5 per cent solution of hydrochloric (muriatic) acid or acetic acid can be used. These acids can burn the skin, so rubber gloves must be worn. All worn or damaged feeder parts should be replaced while the equipment is dismantled. An ample supply of essential parts should be available, including diaphragms, ball valves, poppet valves, valve seats, and orifices. Reference should be made to the manufacturer's manual for a complete list of such parts. All instructions of the manufacturer for oiling and greasing of equipment should be followed explicitly. Too much lubrication can sometimes be as bad as too little.

Gas Chlorinators

Since chlorine gas in cylinders is under pressure, it is possible to feed chlorine gas directly into a water supply without putting the chlorine into solution in the chlorinator. This

method is seldom used, and possible applications should be discussed with chlorinator manufacturers.

The amount of chlorine gas obtainable from a 150-lb cylinder depends on the pressure inside the cylinder, and this pressure depends upon the temperature of the liquid chlorine. When air temperatures around the cylinder are low, the pressure of gas at the cylinder valve will be in the neighborhood of 25 lb/sq in. As the temperature of the liquid increases, chlorine evaporates more rapidly and cylinder gas pressure increases. This change promotes more gas through the cylinder valve. The following table illustrates the temperature-pressure relationship:

Temperature of Liquid Chlorine---F	Pressure at Cylinder Valve---psi
60	72
80	86
100	140

Note that a temperature increase from 60-80 F results in only a minor pressure increase (14 psi) but that a further increase to 100 F results in an appreciable pressure increase. Such variations in the temperature-pressure relationship make regulation of the amount of chlorine being fed difficult. Some gas chlorinators are, therefore, designed to reduce the pressure of the gas to approximately atmospheric pressure and then to control the rate of flow by various means.

The bell-jar chlorinator. Many of these once almost universally used chlorinators (Fig. 6.2) are still in use. These chlorinators introduce chlorine gas into a bell jar sitting in water via a pressure-reducing valve operated to maintain a low vacuum within the jar. A higher vacuum produced by an injector draws chlorine from the bell jar through an orifice tube calibrated to meter the chlorine. Chlorine feed is varied by raising or lowering this injector vacuum. The measured chlorine is placed in solution as it passes through the injector throat, and the strong chlorine solution is then applied to the water to be chlorinated.

Most of the mechanical parts in the bell-jar chlorinator will function satisfactorily for many years. Some parts, however, require attention at regular intervals. Strainers in the water lines should be removed and cleaned every month or two.

The water injector, probably the most vital part of the equipment, should be dismantled, inspected, and repaired annually.

Equipment inside the bell jar should be cleaned of encrusted material as necessary. Consult manufacturer's bulletins for complete maintenance instructions.

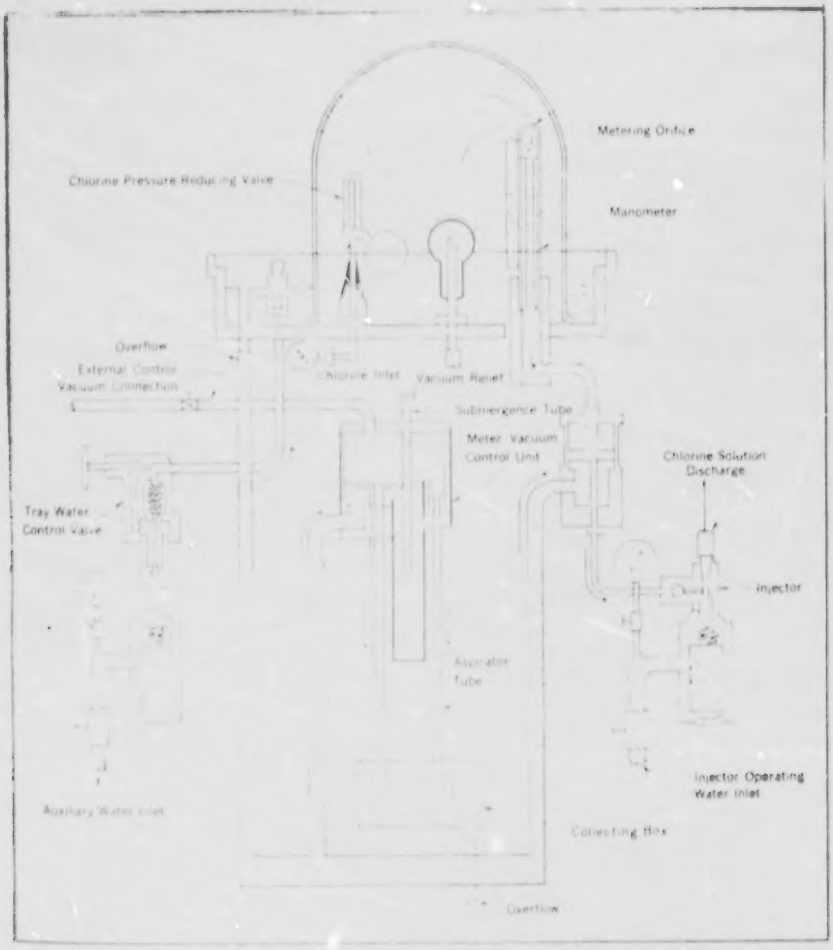


Fig. 6.2 Diagram of a Bell-Jar Chlorinator

As mentioned, bell-jar-type chlorinators were for many years the accepted equipment for feeding chlorine gas in water-treatment plants. Many thousands are still in use, although some manufacturers have completely discontinued their production in favor of more modern equipment. Acceptance of newer designs has been widespread, and the new water-plant operator will be faced with the operation of such equipment. Some knowledge of the basic principles of modern chlorinators is, therefore, desirable.

The diaphragm is utilized in most modern gas chlorinators for controlling conditions affecting the flow of chlorine gas.

Modern chlorinators have been described as consisting of various combinations of pressure-reducing valves actuated by mechanical diaphragms or hydraulically operated floats, orifices, or other types of meters for measuring the rate of flow of chlorine gas after it has been reduced to a uniformly low pressure. Devices are incorporated for making an aqueous solution of the gas and injecting this solution into the water.

In some chlorinators the diaphragm-regulator units are mounted separately for ease of inspection and adjustment. Repairs and replacement of parts can be made by following instructions in the manufacturers' manuals. In other chlorinators, all diaphragm regulators may be "piled" together in single units. These are termed "stacked" diaphragm systems. The inexperienced operator should never attempt repairs on such a unit because special tools are required to reassemble the components. If any trouble arises, the operator should contact the manufacturer's representative for experienced assistance before taking countermeasures.

The variable orifice used in the bell-jar chlorinator is considered a fixed orifice because once installed in the equipment its area always remains constant. Naturally, the orifice tube can be changed for a larger or smaller orifice; but once installed, the area of the opening remains constant. The chlorine gas feed rate is altered by making changes in the degree of vacuum pressure that exists inside the orifice tube.

Most modern chlorinators emply a method whereby the size of the orifice can be changed to control feed of chlorine gas. Vacuum is utilized throughout the entire system, and the degree of vacuum on both sides of the orifice is very closely controlled.

Regulation of dosage usually desired in water treatment is accomplished by partially plugging the orifice opening. A cone-shaped plug is positioned to move up into the orifice and, ultimately, completely close it. Movement is accomplished with a knob adjustment, as shown in Fig. 6.3, which moves the cone up or down as desired. The orifice opening can be very closely controlled to give the required flow of gas.

The V-notch orifice is a more recently designed method for regulating the flow of chlorine gas by varying the size of the orifice opening.

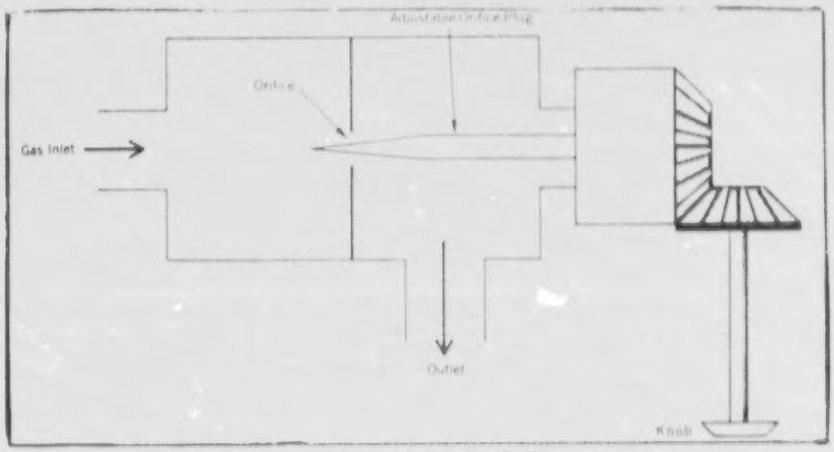


Fig. 6.3. A Variable Orifice

The amount of chlorine gas fed into the system is controlled by adjustment of the screw knob.

Calculating Chlorine Gas Dosages

All chlorinator meters give feed rates in lb/24 hr. Often, the dosage is reported in lb/mil gal or in ppm. Since chlorine feed is reported in pounds, measurements of water being treated must also be converted to pounds. Each gallon of water weighs 8.34 lb; therefore, 8.34 x mgd = lb of water in millions. The following equation applies:

$$\text{Dosage (in ppm)} = \frac{\text{lb chlorine/24 hr}}{8.34 \times \text{mgd}}$$

For example, chlorine is being fed at the rate of 40 lb/24 hr during which time 1.2 mil gal of water are treated. Therefore:

$$\text{Chlorine dosage} = \frac{40}{8.34 \times 1.2} = 4.0 \text{ ppm}$$

Accuracy of the feeding equipment can be determined by checking the machine reading with the actual amount of chlorine gas being released from the chlorine cylinders over a 24-hr period. For example, if the chlorine feed rate is set consistently at 40 lb over an entire 24-hr period, the loss in weight on the cylinder scales over this same period of time should also be 40 lb. Shorter periods also can be used for such a calibration.

Delivering Chlorine Solution

A chlorine solution, whether it is chlorine gas dissolved in water or a hypochlorite solution, can be very corrosive. Lines carrying solution from the feeder to the point of application must be resistant to chlorine solution attack. Rubber is fairly resistant, and rubber-lined steel pipe has been used successfully. Rubber hose can also be used, but must be strong enough to withstand the internal pressure of the solution. Kinking or sagging of the hose should be avoided.

Some types of plastic pipe are also quite resistant to corrosion by chlorine solution and are quite frequently used.

The following precautions for chlorine solution feed lines should be observed:

1. Make lines as short as possible.
2. Provide suitable supports to eliminate kinks or sags.
3. Protect the line from any possible mechanical injury, yet leave it accessible for repair.
4. Minimize the number of fittings in the line, such as elbows and valves, which can offer an amazing amount of resistance to the flow of chlorine solution.

Point of Chlorine Application

At one time or another, chlorine has probably been applied at practically every conceivable point in a water system.

One very important factor to be considered is the water pressure at the point of application. Most hypochlorinators are designed to deliver hypochlorite solutions against high water pressures e.g., 60-125 psi, and even higher with some units. Therefore, water pressure is seldom of any concern where hypochlorinators are used.

Caution may be required, however, in the case of a gas chlorinator where a water injector is used to force the chlorine solution to the point of application. If the chlorine solution is discharged to water under pressure, such as in a pipeline, the water being delivered to the injector must be at a pressure 2½-3 times greater than the pressure in the pipeline.

Spare Chlorine Feeders

There are many reasons for failure of a chlorine feeder to function properly. Most of them may be very minor, and promptly corrected by a knowledgeable operator. When repairs require periods longer than a few minutes, there is the danger of delivering non-chlorinated -- therefore possibly unsafe -- water to consumers. This danger is avoidable if a spare chlorine feeder is available and can be put into service immediately. Many water plants have spare feeders as insurance for emergencies. This is considered to be good operating practice.

Reporting Emergencies

The water-plant operator must report any situation that results in delivery of unchlorinated water for any longer than a few minutes. The report should be made as quickly as possible, by telephone or other means of rapid communication. Also, at the earliest possible moment, the operator should submit a detailed written report to his immediate supervisor. The operator would be well advised to retain a copy of this written report in his files. Naturally, the responsibility of reporting the situation to others falls to the supervisor.

DISINFECTION OF WATER (CHLORINATION)*

The delivery of a water free at all times of disease transmitting organisms is the primary concern of the water works operator. In order to capably discharge this responsibility under all circumstances, his knowledge must go beyond that necessary to introduce a bactericidal agent into the water. He should be aware that the common water-borne diseases which may be transmitted through his supply are typhoid fever, paratyphoid fever, bacillary dysentery and amebic dysentery; also that infectious hepatitis may be spread by water and that there is considerable evidence that poliomyelitis may be so spread. Chapter III, Communicable Diseases, reveals that the responsible agents of these diseases are bacteria, cysts, and viruses all of which have a common source---human excreta. Coupling this with knowledge that the coliform bacteria found in his water samples may have had the same origin (human waste) should be sufficient evidence or warning of the potential danger. The operator should understand that since there are so many more coliform organisms than disease producing organisms, and since they both originated from the same or similar sources, that a laboratory report of the absence of coliforms is taken as sufficient evidence that pathogenic bacteria are also absent. Other interesting items of information the operator should possess are: (a) That, although they are very small, most of the infectious bacteria can be removed by coagulation and settling---just as is colloidal matter. (b) That even though these are fragile creatures they tend to die off quickly in water, but many survive for long periods even under adverse conditions. Thus storage may effect quite a reduction in the disease producing bacteria population. (c) That bacteria are relatively easy to kill by disinfection but cysts and viruses are much hardier. (d) That preventive measures to keep harmful matter out of the supply are better than trying to destroy it after it is present.

In order for the operator to do the best job he should know something of various disinfecting agents, their application, complications (such as taste and odors) which may result from application of disinfectants, auxiliary benefits received by application of certain additional chemicals, means and points of application, etc.

DISINFECTION

After reading and reflecting upon the following definitions the operator will no doubt want to use the word "disinfection"

*Source: Water Works Operators Manual, Third Edition, 1972, Alabama Department of Public Health, Bureau of Environmental Health, Montgomery, Alabama. Chapter XVII.

rather than "sterilization" in his discussion relative to treatment of water. Proper use of words and terms reflect ones familiarity with the subject.

The term "disinfection of water" may be generally defined as the treatment of water by physical or chemical means to destroy the active bacterial contamination, including those microorganisms known to be pathogenic or infectious. "Sterilization of water" may be defined as treatment to completely destroy all living organisms, which may be in the water.

The operator attempts to destroy such organisms as might be dangerous as it would be rather difficult and unnecessary to sterilize the water.

TYPES OF DISINFECTION

(I) Heat---Boil for 5 to 10 minutes. Possibly the first used method of disinfection. Good for small household quantities of water when bacteriological quality can be questioned.

(II) Radiation---Ultraviolet light. Absorption of ultraviolet light is very rapid, hence the use of this method limited to clear water in close contact with lamp. Impractical as a method of treating large quantities.

(III) Chemicals--- (a) Metals---Oligodynamic action by metal ions.

(1) Silver---Traces of silver in water have long been known to have bactericidal properties. Very slow process and impractical. Introduced by electrolytic methods using silver anodes or by adding silver nitrate.

(2) Copper---Copper sulphate (bluestone)---not very effective.

(b) Caustic lime to causticity i.e., free $Ca(OH)_2$ (pH 10 or above). Incidental to water softening.

(c) Oxidizing Agents.

(1) Potassium permanganate---Much used in wells in India (cholera). Slow, expensive. Used in removal of iron and manganese and for the control of tastes and odors.

(2) Ozone---formed by discharging electricity in dry air--Expensive.

(d) Cyanuric acid. Since 1958 chlorinated cyanurates and cyanuric acid (used with chlorine) have been used in swimming pools to assist in maintaining the chlorine residual. The cyanuric acid stabilizes hypochlorite chlorine against the effects of sunlight thereby preventing the chlorine residual from being dissipated. At the present time the cyanurate concentration cannot exceed 100 ppm in swimming waters.

(e) Halogens.

(1) Iodine---available as tincture of iodine---Relatively expensive. Emergency disinfection of small quantities for

drinking purposes. Two (2) drops of 7% solution per liter of water.
(2) Bromine---related to chlorine---less active---Supply limited no suitable residual test.
(3) Chlorine---The use of this chemical in water for disinfection and its other beneficial affects will be discussed at length. The remainder of the Chapter will be devoted to chlorine and the following one to the operation and maintenance of chlorinators.

CHLORINATION

Chlorine was discovered by Schelle, about 1774. It was named by Davy after Chloros meaning green. It has been used for disinfecting water for about 60 years, being used first in 1908 in Jersey City. It is used in practically all large supplies and many small ones. In Alabama all water supplies are disinfected, and chlorine is the agent used. It is a satisfactory disinfectant, since small doses kill bacteria rapidly and a moderately stable residual can be maintained for continued bactericidal action. The disinfecting residual produces no harmful effects on consumers.

Chlorine is a greenish-yellow gas possessing a pungent and irritating odor. It is heavier than air, non-inflamable, and non-explosive. Chlorine, when loosed to the atmosphere is toxic and corrosive, but methods have been developed whereby it can be stored, handled and applied to water without appreciable hazard. Chlorine as used in purifying water may be either the pure substance or in the form of compounds capable of releasing chlorine when dissolved in water. Chlorine is a very active chemical element and when added to water it immediately attacks any dissolved or suspended material capable of combining with it. It is for this reason that chlorine is such a valuable agent in disinfecting water, as living bacteria are readily killed with the action of the chlorine on the organic material which forms their cells. Upon being added to water it combines with the liquid itself forming hypochlorous acid which is a powerful oxidizing and germicidal agent. Pure, dry chlorine is non-corrosive to iron; however, in the presence of moisture it is extremely corrosive. This is the reason that platinum, silver, glass and hard rubber or other similar material must be used to resist the action of damp chlorine or chlorine solutions.

PURPOSE OF CHLORINATION

The primary purpose for adding chlorine to the water supply is of course to disinfect or kill the bacteria therein. It is indeed fortunate that the pathogenic organisms responsible for the common water-borne diseases succumb rather easily to the action of chlorine. As was noted in the beginning of this Chapter, some forms of disease producing organisms such as cysts and

viruses are harder to kill. Some types of bacteria, such as spore formers, are extremely resistant to chlorine; however, many of these resistant types of bacteria are non-disease producing. In addition to its use as a germicide, chlorine is also valuable in color removal, in improving coagulation, as an aid to filtration by keeping sand beds clean, and as a remover of taste and odor by destroying the compounds responsible.

SOURCES OF CHLORINE

Sources of chlorine used in water treatment are: (1) liquid chlorine (gas), (2) hypochlorites of calcium, (3) sodium hypochlorite. Most of the chlorine used in this State is purchased in the form of liquid chlorine. The term "liquid chlorine" should not be confused with liquid hypochlorite, laundry bleach. Liquid chlorine is the compressed chlorine gas. It is shipped in steel cylinders having capacities of 150 pounds and one ton. Several of the larger plants in the State use ton cylinders. The advantage of this is the reduction in price, however, a plant must use 50 to 75 pounds per day before ton cylinders may be considered solely from an economic standpoint. Chlorine as a liquid is usually better than 99.5% pure, a fact that makes this form particularly desirable.

Prior to the use of liquid chlorine for water treatment, hypochlorite compounds were the source of this chemical. When mixed with water these compounds liberate chlorine and produce oxygen and hypochlorous acid in a similar manner to liquid chlorine.

Hypochlorite of calcium is available in several forms. Until recent years the best known of these were chlorinated lime or bleaching powder. This is a lumpy white powder which decomposes slowly at ordinary temperature with the loss of chlorine. Chlorinated lime contains a large amount of inert material, mostly lime and has an available chlorine content of only about 33%. Chlorinated lime suspensions or solutions are very unstable.

In recent years improved calcium-chlorine compounds are available which are more nearly true chlorites and have a chlorine content of 65 to 70%. These hypochlorites are in the form of a stable free flowing white powder readily soluable in water forming solutions that are fairly stable. Calcium hypochlorite is used in a few of the small water supplies over the state. It is fairly satisfactory when properly handled. These compounds should be dissolved or mixed with water and allowed to settle. After a satisfactory settling time the clear liquid should be syphoned or drawn off into the solution container from which the feeder (hypochlorinator or metering pump) takes suction. This method of handling prevents the calcium deposits from clogging the feeder.

Largely because it is much easier to handle, sodium chlorite has gained favor over the calcium hypochlorite as the source

of chlorine in the small plants. Sodium hypochlorite is a greenish-yellow liquid having the disagreeable chloronous odor and contains about 14% available chlorine. It is usually shipped in gallon plastic containers, however, larger carboys are available and less expensive. Considering the amount of chlorine available this compound may be slightly cheaper in costs than the calcium hypochlorites. Since the material is already a solution and there are no solids to clog the feeder, sodium hypochlorite is being commonly used.

FACTORS INFLUENCE CHLORINATION PRACTICES

A number of substances may be present in water which will influence chlorination. Some of these are: (a) suspended solids, (b) organic matter, (c) ammonia, (d) high alkalinity, (e) nitrates, (f) manganese, (g) iron, and (h) hydrogen sulfide. In addition to these constituents, the temperature of the water influences chlorine practices. At higher temperatures chlorine is more effective; however, it is more stable in cold water and will thus remain in the water longer, making up in some measure for the slower rate of disinfection. The contact time, i.e. the period of time available for reaction between chlorine and substances in water, is a vital factor in chlorination. The minimum contact time should be at least thirty minutes and several hours is much better. This means that there should be a lag of at least 30 minutes between the time the chlorine is added and mixed with the water supply and the time it reaches the first consumer. This infers that if a sample is tested immediately after chlorine is added the residual found will most probably be different than that found minutes later. The chlorine residual is the amount of chlorine remaining in the water after the reaction has been completed. It is that remaining in the water after the chlorine demand has been satisfied.

The factors mentioned above which adversely affect chlorination are overcome when sufficient chlorine is added to react with the organic matter, ammonia, iron, manganese and other reducing substances and leave sufficient excess or <u>residual</u> chlorine for disinfecting purposes. The concentration of residual chlorine should be so selected as to compensate for the deleterious influences of high alkalinities, low temperature or short contact periods.

CHLORINE REACTIONS

Upon the addition of chlorine to water the immediate reaction is the formation of hypochlorous acid and hydrochloric acid. The chemical equation for this is:

$$\underset{\text{(chlorine)}}{Cl_2} + \underset{\text{(water)}}{H_2O} \rightleftharpoons \underset{\text{(Hypochlorous acid)}}{HOCl} + \underset{\text{(Hydrochloric acid)}}{HCl}$$

The hypochlorous acid (HOCl) is a weak acid but a strong oxidizing (helps other materials to take on oxygen) and germicidal agent. The hydrochloric acid (HCl) in the above equation is a strong acid but retains more of the properties of chlorine. It will tend to lower the pH of water especially in swimming pools where the water is recirculated and continuously chlorinated. The total hypochlorous acid and hypochlorite ions in water constitute the free available chlorine.

The hypochlorites act in a similar manner when added to water, since hypochlorous acid is formed. The equation for the reaction when calcium hypochlorite is used is:

$$Ca(OCl)_2 + 2H_2O \rightleftharpoons 2HOCl + Ca(OH)_2$$

(Calcium hypochlorite) (Water) (Hypochlorous acid) (lime or calcium hydroxide)

The hypochlorous acid (HOCl) breaks down (ionizes) in the manner indicated by the following equation:

$$HOCl \rightleftharpoons H^+ + OCl^-$$

(Hypochlorous acid) (Hydrogen iron) (Hypochloric ion)

The symbol "$\rightleftharpoons$" indicates that the reactions are reversible and are dependent upon the pH of the water. At high pH values the hydrogen ions are tied up by alkaline hydroxyl (OH^-) ions to form water and leaving hypochlorite ions which are less active in oxidizing and disinfecting.

The free available chlorine (hypochlorous acid and hypochlorite ions) is very active in contact with organic and other reducing substances in water. It is particularly active in contact with ammonia (NH_3) and other nitrogenous compounds and forms chloramines. The equation for the reaction of hypochlorous acid (HOCl) and ammonia (NH_3) is:

$$HOCl + NH_3 \longrightarrow NH_2Cl + H_2O$$

(Hypochlorous acid) (Ammonia) (Mono chloramine) (Water)

As the amount of chlorine is increased as compared to the ammonia other types of chloramines are formed, such as: (1) dichloramine ($NHCl_2$), (2) trichloramine (NCl_3) or nitrogen trichloride. These compounds are much less active chemically than the free available chlorine and are known as combined available chlorine.

To summarize: (a) Compounds formed when chlorine reacts with ammonia and nitrogenous matter forming chloramines has only moderate disinfecting power and are called combined available chlorine. (b) In contact with reducing compounds such as hydrogen sulfide (H_2S) and manganese (Mn) inert substances are formed which have no disinfecting capacity. (c) The substances formed when chlorine and organic matter react are of little value as disinfectants. (d) The chlorine as hypochlorous acid and hypo-

chlorite ions, remaining in the water after the above reactions are complete, is known as free available chlorine and is a very active disinfectant.

CHLORINE DEMAND

The chlorine demand of a water is the amount of chlorine necessary to react with the organic and other substances present in that water. The chlorine demand will vary with different waters and may vary from time to time in the same water. To illustrate: If a chlorine dose of 0.5 ppm were added to distilled water and after a contact time of ten minutes the chlorine residual test, properly made, indicated a residual of 0.5 ppm, the demand would be zero because no chlorine had been used up. In a sample from a clean lake, 0.5 ppm chlorine might be added and after 10 minutes if it were found that the residual was 0.1 ppm the chlorine demand would be 0.4 ppm. In river water 2.5 ppm is added and after the 10 minute period the residual test indicated 0.5 ppm the demand of this water would be 2.0 ppm. Therefore the demand is, the difference between the amount of chlorine added and the amount of residual after a given contact time.

CHLORINE RESIDUAL

The amount of chlorine found in the water after the contact period, which should be at least 10 minutes, is the chlorine residual. It is important to know whether the residual exists as a free chlorine or a combined chlorine residual.

FREE RESIDUAL CHLORINATION

Some ten years after the use of chlorine was begun the orthotolodine test was developed. Following this the practice was to add enough chlorine so that a residual of 0.1 to 0.2 ppm would result after a reaction time of ten minutes. This was generally satisfactory, however, in some cases it was found that the small doses combined with the ammonia present and formed chloramines. However, the slow disinfecting action obtained was offset by the stable combined chlorine and it was noted that there was little or no reaction with the taste and odor producing compounds. This led to the deliberate introduction of ammonia to form the stable chloramines. Later it was realized that without very long contact time the chloramines possessed very poor disinfecting qualities, unless water of low alkalinity was being treated. This led to application of heavy chlorine dosages, without the addition of ammonia. For a time the term superchlorination was commonly used to indicate heavier than usual chlorine doses. This term has become more or less obsolete, giving way to the phrase breakpoint chlorination and this is being superseded by free residual chlorination.

If enough chlorine has been added to the water to complete the destruction or combustion of the organic matter or ammonia the residual will be present as free chlorine. As has been mentioned, the combined chlorine is much less effective than the free available chlorine residual. The latter is preferred because in addition to its greater disinfection effectiveness it destroys many taste and odor producing materials, gives appreciable aid in coagulation, removal of iron and manganese and controls algae growths.

To illustrate and compare the disinfecting powers of the two types of residuals---a 0.6 ppm combined residual requires about 60 minutes to produce the same degree of disinfection or bacterial kill as will be obtained by 0.05 ppm of free chlorine in ten minutes. When the long contact period of one hour cannot be utilized either a free chlorine residual must be produced, by adding sufficient chlorine, or a combined chlorine residual of 1.8 ppm or 2.0 ppm must prevail. In addition, free chlorine is stable, i.e., it persists in water because the organic matter that would otherwise react and remove chlorine has been oxidized. Free residual chlorine has no taste when present in quantities commonly used in the disinfection of water though some users may detect a slight chlorine odor when the water is first drawn from a tap.

MAINTAINING A FREE CHLORINE RESIDUAL IN DISTRIBUTION SYSTEMS

Many times the operator may feel that the practice of free residual chlorination would be advantageous and attempt to begin the practice only to run into taste and odor troubles. This trouble may be caused by a free chlorine residual in the water leaving the plant coming in contact with pipe slimes or coatings with which the chlorine reacts or oxidizes. As the progressive oxidization of this coating takes place, further and further out into the mains, the taste and odor complaints will progress outward along the line. As this progression takes place, complaints should subside as the complete cleaning of the line takes place.

In addition to prolonging the disinfecting period, the maintenance of free residual chlorine in the distribution system has at least two other advantages:

(a) The prevention of the reduction of sulphate of hard waters to sulfides when the water remains in dead ends. (Sulfides produce taste and odors); (b) The prevention of growths of organisms which tend to decrease the capacity of mains.

The above mentioned benefits accrue when chlorination is introduced at the intake of raw water transmission mains. Perhaps the prevention of growths in these lines is the item which would merit much consideration and be a determining factor.

PRECHLORINATION AND POST CHLORINATION

Pre-chlorination is the application of chlorine at any point ahead of filtration. The many advantages of pre-chlorination have led to the rather universal application of chlorine as one of the first steps in processing the water for filtration. Application of chlorine at the beginning of the treatment process gives a long contact period for maximum disinfection benefits, aids coagulation and sedimentation (especially of colored waters) oxidizes iron and manganese, destroys taste and odor producing matter and keeps down bacterial and algae growth in settling basins, filters and storage facilities.

Raw water has a much higher chlorine demand than filtered water, therefore the cost of pre-chlorination as compared to post chlorination is somewhat more. The added cost of chlorine, however, is more than compensated for by the improved treatment, reduction in complaints, longer filter runs and in various other ways. The pre-chlorine dose may vary from 0.5 ppm to 5.0 ppm or more depending upon the organic and mineral content of the water. As a general rule a chlorine residual of a minimum of 0.3 to 0.5 ppm should be maintained on top of the filters. It will be found that the season of the year and the weather on any particular day (clear or cloudy) will cause the chlorine residual to vary.

It was formerly thought that pre-chlorination was detrimental when practiced in connection with slow sand filters. Experience has shown, however, that there are advantages to such treatment in that algae growths are destroyed and the bacterial load is reduced.

Post chlorination is the application of chlorine after filtration. It should be the second or last stage of chlorination and it is through the regulation of this dose that the desired free available residual is obtained. It is doubtful that post chlorination should ever be the only chlorination. The exception to this would be where it is learned that there are certain materials in the water which other treatment processes will remove thus preventing their reaction with chlorine which otherwise would result in taste and odor problems.

Precautions should be taken against the interruption of the addition of chlorine to the water. For this reason two feed machines must always be provided for surface water supplies. It is common practice to have one machine for addition of chlorine to the incoming water and one for filtered water. Even where duplicate equipment is available spare parts for repair should be kept on hand. Needless to say this is especially important where chlorination is dependent upon one feeder.

Regardless of the point of application the machine feeding the chlorine or hypochlorite to the water should be checked often and the chlorine test made frequently enough that the operator is absolutely sure all water delivered to the distribution

system is adequately chlorinated. Where liquid chlorine is used the cylinders should be placed on accurate scales so that the quantity used each day and the amount left in the cylinder is known. An accurate record of these weights should be kept.

CHLORINE FEEDERS

Chlorine is applied to water by using chlorinators, hypochlorinators, homemade solution feeders and in case of emergency by hand.

CHLORINATORS

Chlorinators are feed machines or devices for delivering liquid (gaseous) chlorine from cylinders to the water. They may be classified in the following ways:

(1) Direct feed or solution feed, depending upon the way the chlorine is added. Direct feed is the application of the chlorine in the form of gas to the water through a diffuser. The solution feed machine dissolves the gas in a small flow of water and the solution is fed to the desired point of application. In cases where the solution is fed to a main or the point of application is under pressure the solution must be injected or pumped.

(2) There are pressure and vacuum types depending upon the device for controlling the flow of gas within the chlorinator. Most machines are of the vacuum type.

In the vacuum controlled chlorinators the gas enters through an inlet valve so designed that it is closed at all times except when sufficient negative head is produced by an injector operated by the water and used to form the solution water for the gas.

HYPOCHLORINATORS

Hypochlorinators (chemical metering pumps) are devices (usually diaphram type pumps) to feed hypochlorite solution to water. The dose may be varied by varying the strength of hypochlorite solution or by varying the rate of pumpage. The pumping rate is usually changed through variable motor pulleys or by changing the length of stroke of the pump. These machines are usually driven by electric motors, however, there are other methods of powering them including a water driven mechanism. Hypochlorinators can be made automatic or semiautomatic by so connecting them to the power supply that they will start and stop with the pump.

Chlorination is essential to the production of a safe water. Equipment used in the addition of chlorine to the water supply is relatively expensive and specialized. For these rea-

sons it is essential that the equipment to be used in this phase of the treatment be properly selected, installed and maintained. Adequate reagents and equipment should be available and used frequently to check the results.

SAFETY FIRST

Where gas chlorine is handled -- ALWAYS KEEP A BOTTLE OF CONCENTRATED AMMONIA HANDY AND CHECK FREQUENTLY FOR LEAKS.

Improperly handled chlorine can be deadly. The best precaution against chlorine hazards is prevention. Hazards can be eliminated by properly locating and housing chlorination equipment, following operating instructions and adequate maintenance by properly trained personnel.

The building housing chlorine and chlorine feed equipment should be provided with forced draft ventilation. An exhaust opening should be provided near the floor level. A fan may be provided in this opening to draw air from the room or a fan may be provided near the roof to take in air to be forced out the opening. In either case the switch for the fan should be located outside the room. The fans should exhaust the chlorine room atmosphere to a point outside the building.

CHLORINE LEAKS ALWAYS GET WORSE, OFTEN VERY QUICKLY: therefore any detectable leak should be located and stopped at once. Not only is the chlorine gas loose in a confined space dangerous, but it will cause electrical switches and other controls to corrode quickly and ruin. It will be interesting to note that 3.5 parts of chlorine gas in a million parts of air is the amount required to give the least detectable odor. The maximum amount that can be breathed for one hour without serious effect is 4 parts to a million parts of air. In other words, when chlorine odor is noticed it can quickly become serious. Areas containing enough chlorine to cause coughing should be avoided. Coughing causes deep breathing and deep breaths of heavy concentrations of chlorine is extremely dangerous.

Just any type gas mask does not protect against chlorine. Gas masks of a type approved by the U.S. Bureau of Mines <u>for chlorine service</u> should always be readily available where chlorine is stored, transported or used. These should be located (unlocked) outside the probable area of contamination (such as the chlorine room).

Should it ever be necessary to pass through a heavily chlorinated area without a mask remember that chlorine is heavier than air, therefore keep the head high, and keep the mouth closed, avoid coughing or deep breathing and keep physical exertion to a minimum. In case a person is exposed to chlorine the following first aid measures are recommended:

(1) Move patient from gas area. Place him on his back with head and back elevated. Keep him warm and quiet. Rest is essential.

(2) Call a Doctor at ONCE. While there may not be any serious effects from exposure to chlorine, a doctor should always be called.

(3) Milk may be given in mild cases as a relief from throat irritation.

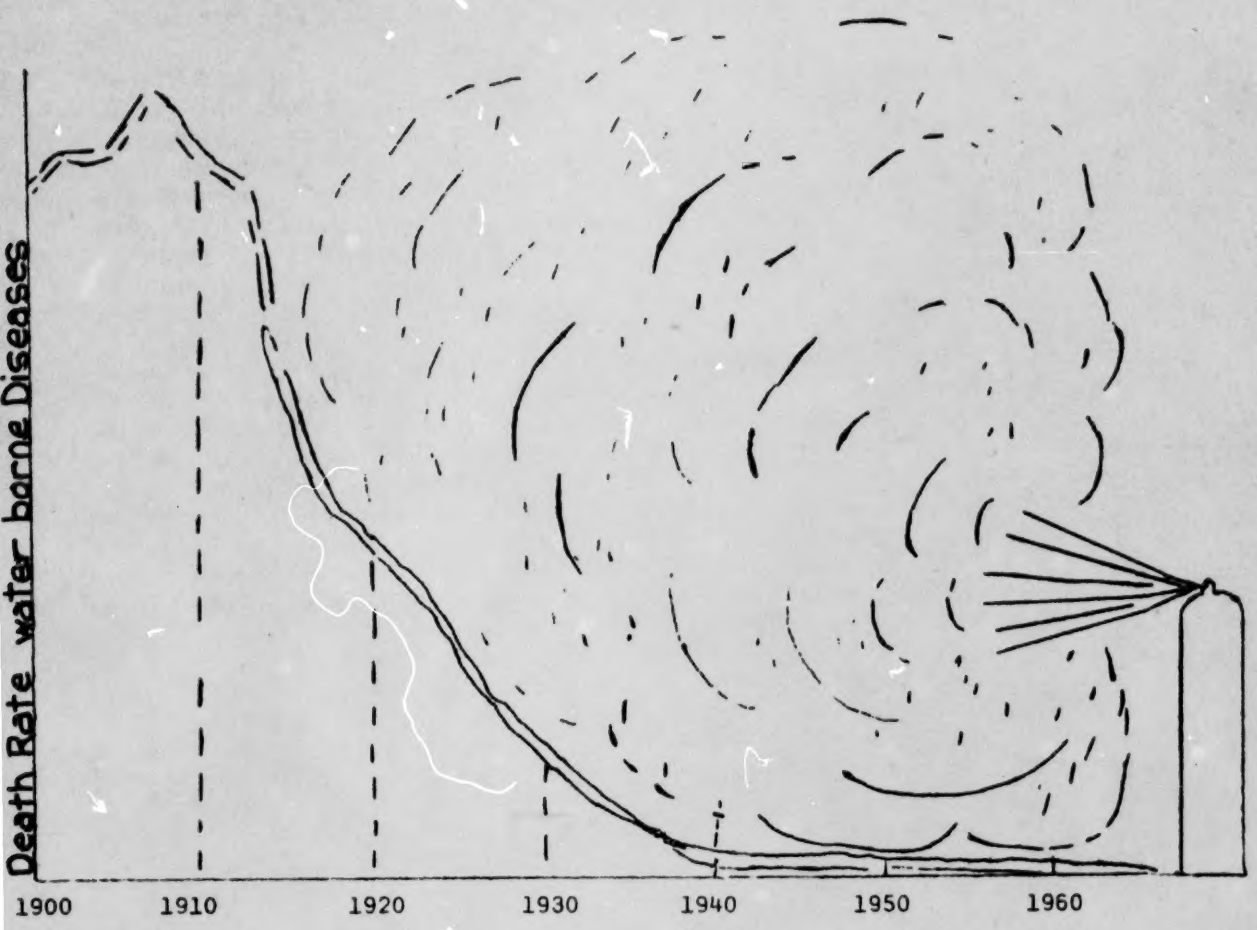
(4) If breathing has apparently stopped, start artificial respiration, prone pressure method at once. Do not exceed 18 movements per minute.

Instructions for handling and using chlorine and operation of chlorinator together with first aid instructions should be placed near the chlorine room door. Personnel should be required to be familiar with these instructions and the first aid methods. Manufacturers of chlorine and chlorinators will provide the literature. The Chlorine Institute, Inc., 50 East 41st St., New York, New York 10017, has published a Manual for Handling and Use of Chlorine.

QUESTIONS

1. Chlorine gas is lighter than air.
   (T) (F)
2. Chlorine is never used to disinfect new wells because it is corrosive.
   (T) (F)
3. Very few metals are corroded by chlorine in a moist atmosphere.
   (T) (F)
4. Chlorine always has a tendency to destroy tastes in water.
   (T) (F)
5. The correct practice when chlorinous taste complaints are received is to increase the chlorine feed rate.
   (T) (F)
6. Water can be disinfected quicker with chlorine at a high pH value than a low pH value.
   (T) (F)
7. "Free available chlorine residuals" refer to those residuals consisting almost entirely of hypochlorous acid (HOCl) and hypochlorite ion (OCl).
   (T) (F)
8. Boiling water will, in a few minutes: (A) destroy pathogenic organisms; (B) will not destroy pathogenic organisms; (C) may at times destroy pathogenic organisms, but not always.
9. What is the purpose of chlorination?
10. Why will different amounts of chlorine be required to insure disinfection of different waters?
11. What is the difference between sterilization and disinfection? Why is sterilization very important in bacteriological laboratory work?

THE CHLORINATION OF WATER



WEST VIRGINIA STATE DEPARTMENT OF HEALTH
Division of Sanitary Engineering
Charleston 5

CHLORINATION OF WATER

Prepared by
Division of Sanitary Engineering
West Virginia Department of Health

INTRODUCTION

Many thousands of lives have been saved the past forty years by using chlorine to disinfect public water supplies. Chlorination of water is now accepted as standard practice, and all public water supplies should benefit from the extra protection afforded by this treatment.

Chlorine is in general use at water plants, swimming pools and sewage treatment plants and a considerable number of persons in West Virginia must be familiar with the installation, operation and maintenance of chlorinating equipment. Since it is practically an every day occurrence for an inexperienced person to be called upon to operate a chlorinator, there is need for an elementary bulletin dealing with this subject. This bulletin has been prepared to instruct and help the beginner.

WHAT IS CHLORINE?

Chlorine, at ordinary temperatures and pressures, is a non-inflammable greenish-yellow gas with a pungent, irritating odor. The gas is 2½ times heavier than air. Chlorine is manufactured commercially by passing an electric current through a solution of sodium chloride (Table Salt). The gas is collected, compressed into a liquid and packaged in steel cylinders. The cylinders commonly used in water plants hold 100 or 150 pounds of chlorine, and when full have a gross weight of about 200 and 275 pounds respectively. The gas is manufactured at many points throughout the United States. (There are 2 plants in West Virginia.) Liquid chlorine costs about 16 cents per pound.

When liquid chlorine is placed in a cylinder, the liquid only partially fills the container and the space above the liquid level is filled with chlorine gas. (Chlorine vapor). The cylinder pressure varies with the temperature as follows:

Temperature Degrees Fahrenheit	Cylinder Pressure Pounds Per Square Inch
30 below zero	0
0	14.5
32	39
68	82
104	150

The cylinder contains liquid chlorine, but when the tank valve is opened chlorine gas is given off (if the cylinder is in an upright position). At ordinary temperatures 30 to 40 pounds of chlorine can be withdrawn from one cylinder during a 24 hour period. Figure 1 is a sketch showing the top of a cylinder, and tank valve.

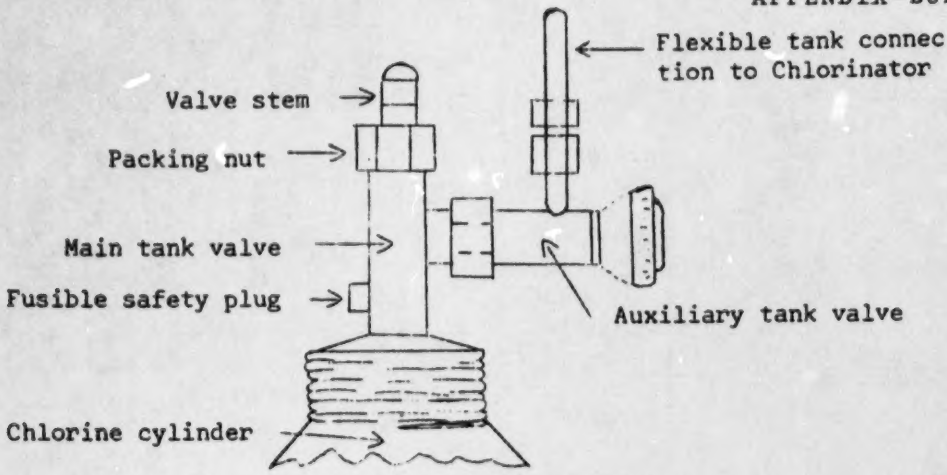


FIG. 1 - TANK VALVE AND AUXILIARY TANK VALVE

HANDLING THE CHLORINE CYLINDER

There is no danger in handling a chlorine cylinder if ordinary care is used. Some of the most important precautions to observe are:

1. Do not drop the cylinder. There is little danger of rupture but the tank valve may be snapped off unless the protective cap is in place. While in position at the chlorinator, the cylinder should have a protective guard strap around it to prevent accidental overturning.

2. Keep the cylinder away from intense heat. The main valve is protected with a fusible safety plug which melts at 157°F. The fuse plug will prevent the cylinder from exploding during a fire.

3. Operate the tank valve with the wrench provided for that purpose. DO NOT USE A STILLSON OR HEAVY WRENCH. In small plants where a cylinder may continue in use for a long time, the tank valve should be operated daily to avoid freezing in position.

4. Operate the cylinder in an upright position. If inverted or placed on the side liquid chlorine will issue from the cylinder when the valve is opened.

5. Leaks around the tank valve stem can often be stopped by tightening the packing nut.

6. If a leak develops in a cylinder, keep the cylinder upright so gas, and not liquid chlorine, will leak out. If possible remove the cylinder to an isolated, ventilated spot. Packing the cylinder in dry ice (carbon dioxide ice) will lower the temperature and stop the leak. If the cylinder can be immersed in a bath of strong soda ash, caustic soda or lime solution, the leaking chlorine will be absorbed and not escape into the air. Never ship a leaking cylinder.

7. Persons handling chlorine should be equipped with a proper gas mask and trained to use the mask. If no mask is available USE DISCRETION IN APPROACHING A LEAK. AVOID DEEP BREATHING. TAKE NO CHANCES.

FIRST AID

A person overcome with chlorine gas should be removed from the gas area, placed in a warm room, and kept warm with blankets while resting on the back with head and back elevated. A physician should be called immediately. Treatment consists of administering the standard oxygen and 7% carbon dioxide by means of an inhalator.

If the patient's breathing has apparently stopped, artificial respiration should be instituted immediately. The most recent development for artificial respiration is the mouth-to-mouth method. The patient's mouth must be cleared of any foreign matter with the middle finger of one hand. With the same finger, push the tongue forward. Place the casualty in a face-down, head-down position and pat him firmly on the back to help dislodge any foreign object in the air passage. Turn the casualty on his back and use the middle fingers of both hands to lift the lower jaw from beneath and behind so it juts out. Hold the jaw in this position with one hand. Place your mouth over the casualty's mouth, tightly enough for a relatively leakproof seal. Breathe into the casualty's mouth with a smooth steady action until you see the chest rise. As you start this action move your free hand to the casualty's abdomen, between the naval and ribs, and apply continuous moderate pressure to prevent the stomach from filling with air. When his lungs are inflated, remove your mouth from the casualty's mouth and allow his lungs to empty. Repeat this cycle, keeping one hand beneath his jaw and the other pressing on his stomach. For an adult, the rate is 12 cycles per minute, and about 20 cycles per minute for a child or infant. The Schaefer prone-pressure method of artificial respiration may be used also, using not more than 18 movements per minute.

Clothing splashed with liquid chlorine or chlorine water should be removed immediately, and the affected area of the skin should be washed with a large volume of water. Resulting injuries should be treated by a physician.

All persons handling chlorine should be trained in first aid measures and drilled in them periodically. Gas masks, approved for chlorine service by the U. S. Bureau of Mines, should be quickly available in storage places that cannot be reached by the gas, and all persons who may have occasion to wear them should be familiar with their use.

High strength calcium hypochlorite compounds are highly combustible and must be stored away from intense heat and open flames. One should not smoke while handling these 70% chlorine compounds. In case of fire in the chlorine storage area, firemen should be warned of the presence of this chemical and shown the location of the containers.

CHLORINE COMPOUNDS

Active chlorine can be purchased in forms other than compressed gas. Where small amounts of chlorine are needed it may be easier to use powdered calcium hypochlorite, or liquid sodium hypochlorite. Many of the smaller water plants use special equipment to feed hypochlorite solution instead of using chlorine gas. The following chlorine compounds are generally available.

High Strength Calcium Hypochlorite - Powdered high strength calcium hypochlorite is sold under various trade names such as HTH, Perchloron, Pittchlor, Penchlor, etc. It is a stable, granular, free flowing material containing about 70% chlorine. It is packaged in 5 pound tins and 100 pound steel drums. A case of nine 5 pound tins costs about $23.00 and a 100 pound drum costs about $34.00. The compound retains its strength for a year or more.

Powdered calcium hypochlorite is widely used in small water plants and small swimming pools, and for such uses as main sterilization, batch dosing tanks, and general sanitation purposes. If a source of supply cannot be found locally, consult the State Health Department.

Sodium Hypochlorite - Laundry bleaching solutions such as Clorox are sold in most grocery stores. These solutions are sodium hypochlorite and contain about 5% available chlorine. They are convenient to use but the cost is quite high. If manufactured locally the cost in 5 gallon carboys may be fairly low. The chief advantage of sodium hypochlorite is that it is available most everywhere, and can be quickly located in an emergency.

HOW MUCH CHLORINE IS NEEDED TO MAKE A WATER SAFE?

Dangerous bacteria in water are quickly killed by a very small amount of chlorine, if the water is clear and not heavily polluted. If the water is muddy, and contains gross pollution, normal doses of chlorine may not be effective.

When chlorine is added to a water, part or all of it may be quickly used up by the organic matter which may be present. This quick using up of the chlorine is called "Chlorine Demand". If more than enough chlorine is added to satisfy the demand, the chlorine which is left over is called "Residual Chlorine". To be sure that enough chlorine has been added to a water a test is made for residual chlorine. (See page 4-5)

Most waters can be sterilized by adding one pound of chlorine to 120,000 gallons of water (approximately 1 part per million). Some well waters contain hydrogen sulphide and in such cases much more chlorine may be needed.

While chlorine acts quickly, to provide a proper margin of safety the chlorinated water should not reach the consumer until the chlorine has been in contact with the water for 20 minutes. This is known as the "Contact Period". In West Virginia the practical minimum standard to be observed is: Enough chlorine must be added to maintain a chlorine residual of 0.2 parts per million after a 20 minute contact period.

DPD TEST FOR CHLORINE RESIDUAL

Note: The following procedure applies to the Hach Model CN-66 free and total chlorine test kit only. Refer to Page 7, Gold Appendix, for other manufacturers of approved DPD Test Kits.

Procedure - Free Chlorine - Fill one tube to the ring (5 ml.) with clear water and place it in the left-hand opening of the comparator (behind the color disc). Fill the other tube to the 5 ml. mark with sample water. Add the contents of one DPD Free Chlorine Reagent Powder pillow to the test sample. Swirl to mix and place it in the right-hand opening of the comparator. It is not necessary that all of the powder be dissolved. Hold the comparator up to light such as a window, the sky, or a lamp, and view through the openings in the front. Rotate the disc until a color match is obtained. Read the mg/l free chlorine (Cl_2) within one minute through the scale window.

Total Chlorine - Follow the same procedure as above for free chlorine residual, but use one of the pillows from the box marked "DPD Total Chlorine Reagent," and let the sample stand for three minutes before using the comparator for a color match. Again, not all of the powder must disolve in order to get accurate readings.

Interferences - If high concentrations of monochloramine (combined chlorine) are present, they may interfere with the free chlorine test after one minute developing time. Bromine, iodine, ozone, and oxidized forms of manganese may also react and read as chlorine.

Caution: Do not leave the color disc where it will be exposed to direct sunlight. The color on the disc will fade and faulty readings will result.

OTHER CHLORINE TESTS

While the complete details of making other tests will not be included in this bulletin, the operator should be advised that other tests are available and should be used under certain conditions.

Test for False Chlorine Residual - Manganese in the oxidized form, nitrites, ferric iron and possibly other substance may yield a color when orthotolidine is added to a sample of water, thus giving a reading when no chlorine residual is present or a higher residual than actually exists. If the operator suspects the presence of a false chlorine residual he may use the "Orthotolidine-Arsenite" tests using the following procedure:

Use 2 test cells labelled A and B. To cell A containing orthotolidine add sample to be tested and after 5 minutes compare with color standards.

The result represents the total amount of residual chlorine plus the total amount of interfering colors.

To cell B containing sodium arsenite solution add a measured amount of water sample, and after mixing, quickly add orthotolidine reagent. (Use 1 cc of arsenite and same aount of orthotolidine). After 5 minutes compare 1 cc of arsenite and same aount of orthotolidine). After 5 minutes compare with color standards. The result represents the interfering colors present.

To obtain the true chlorine residual subtract the reading in cell B from the reading in cell A.

Starch-Iodine Test - The starch iodine test may be used for the accurate determination of chlorine residual.

If potassium iodine solution is added to a sample of water containing residual chlorine, iodine will be liberated in proportion to the quantity

of chlorine present. By titrating with sodium thiosulfate (using starch and an indicator) the amount of chlorine residual can be determined with exactness.

WHERE SHOULD THE SAMPLE FOR THE RESIDUAL CHLORINE TEST BE COLLECTED?

As previously noted, the chlorine should be in contact with the water at least 15 minutes and longer if possible before reaching the consumer, so the sample should not be tested until the 15 minutes have elapsed. If the sample has been collected from a tank or reservoir after an extended contact period then the orthotolidine may be added without delay. If a sample is collected immediately following the point of chlorine application, then the orthotolidine solution should not be added until the 15 minute contact period has elapsed. If possible select a sampling point which will be representative of the supply as it leaves the plant.

The frequency of testing depends on the local situation. If the water is reasonably safe without chlorine and has a uniform demand, then a daily test will suffice. If the water is not reasonably safe without chlorine or if the chlorine demand is apt to vary, then an hourly test is indicated.

WHAT IS A CHLORINATOR?

As previously explained, chlorine is purchased in a steel cylinder and is maintained under a high pressure which increases and decreases with the temperature. A chlorinator is a mechanical device to receive the chlorine from the cylinder, reduce the pressure, regulate the pressure, measure the gas, and apply the gas or a solution of the gas to the water to be treated. The importance of the work it performs makes it ESSENTIAL THAT THE CHLORINATOR BE ACCURATE AND DEPENDABLE.

Two general types of chlorinators are in use. One is known as a direct feed chlorinator, and the other is a solution feed chlorinator. The direct feed chlorinator receives the dry gas from the cylinder and applies it to the water through a diffusor.

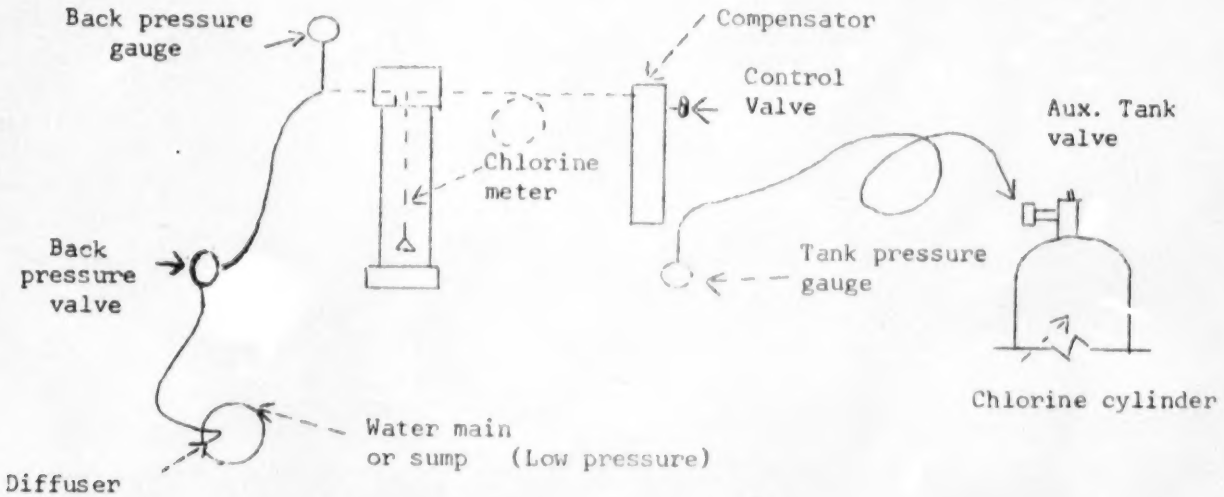
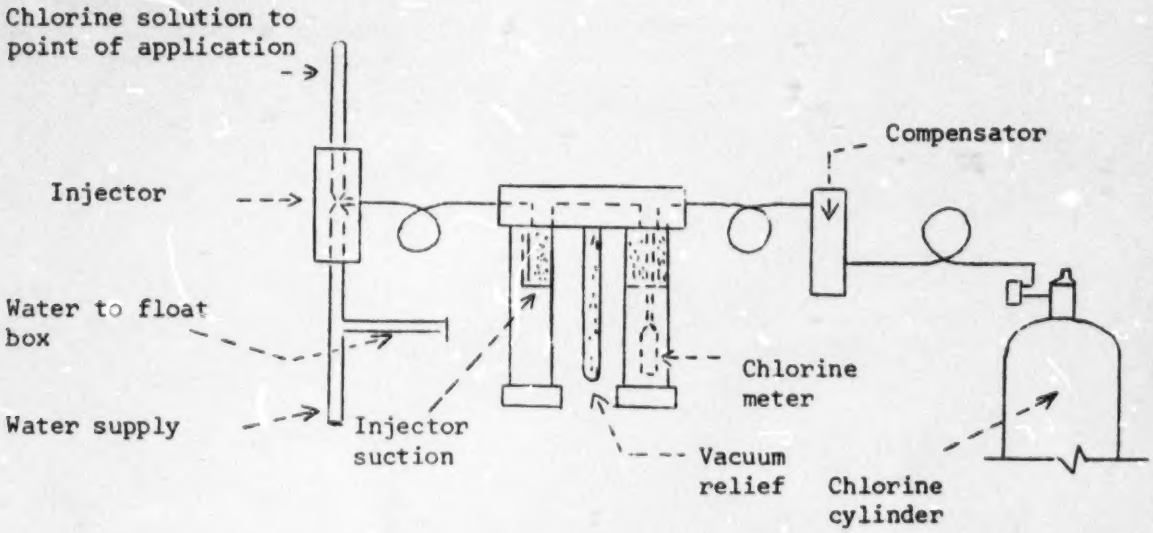


FIG. 2 - FLOW DIAGRAM - DIRECT FEED CHLORINATOR

In a solution feed chlorinator the dry gas is first measured and then combined with water in the machine to make a strong chlorine solution. The solution is then applied to the water to be treated.

There are various makes and styles of solution feed chlorinators in use, but the following simplified sketches explain the basic features of two of the most commonly used gas machines.



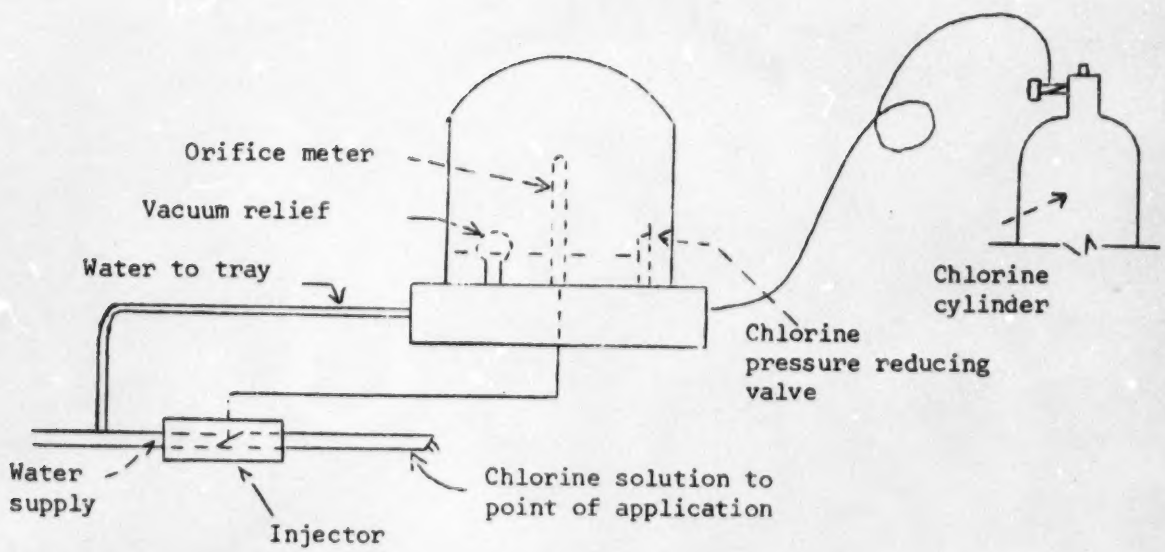
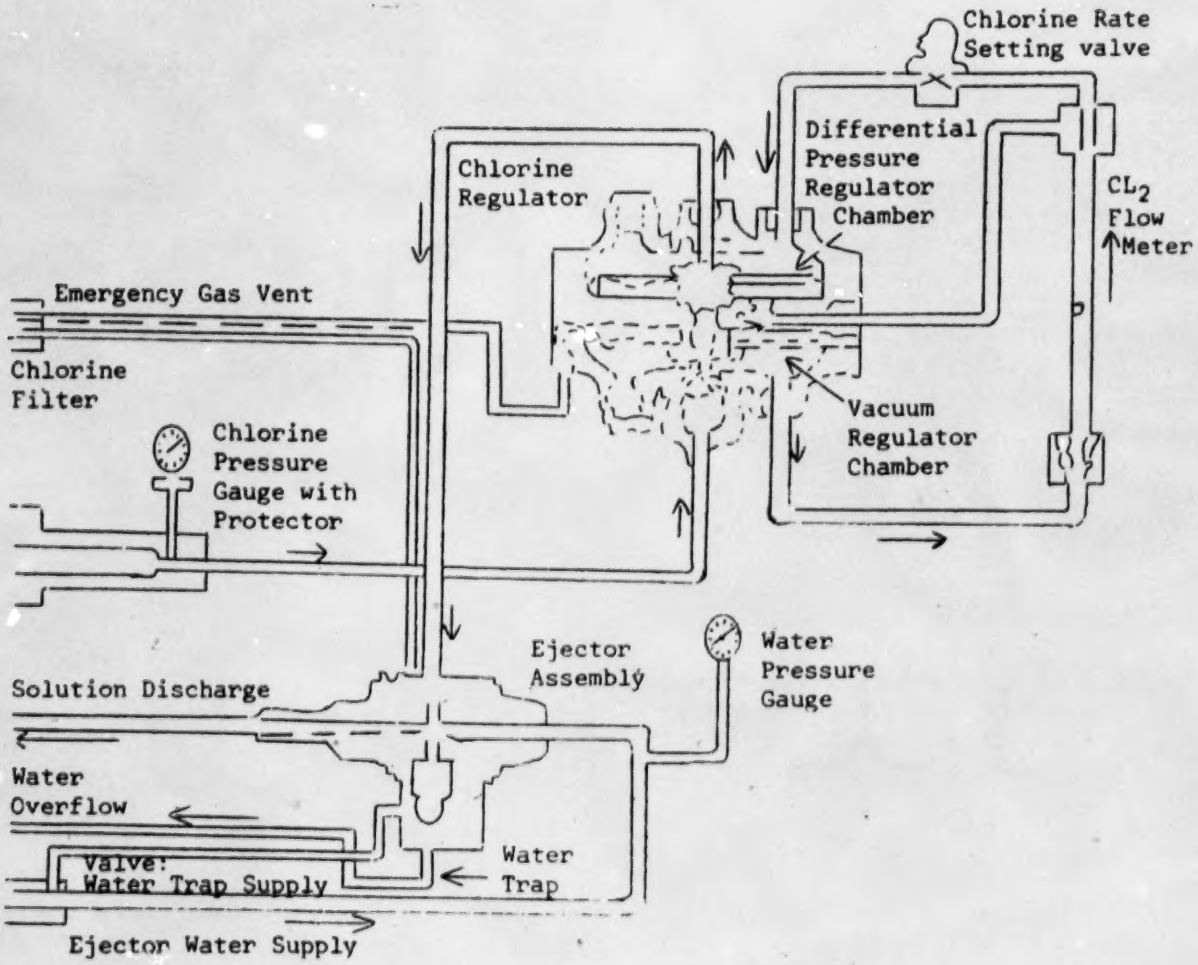


FIG. 4 - FLOW DIAGRAM - VACUUM CHLORINATOR



FLOW DIAGRAM CHLORINATOR

This Vacuum-Type Solution Feed Chlorinator safely combines chlorine and water to provide a sterilizing solution. Chlorine gas is reduced from cylinder pressure to vacuum and mixed at a controlled rate with the ejector water. The rate of chlorine addition can be changed by adjusting a single valve. Flow rate is continuously indicated by a direct-reading meter.

LOCATION OF CHLORINATOR

The location of a chlorinator has a lot to do with the way it will perform. A dark, damp corner in the midst of greasy machinery is a sure way to invite trouble and expense. It is false economy to skimp on the housing and protection of a chlorinator.

1. Provide enough room - at least 3 feet clear space in front and 2 1/2 feet on the sides and back. Have plenty of light.

2. If possible, the chlorinator should be in a separate room with an outside opening. The large installation should have the room equipped with an exhaust fan at the floor level. Avoid a pit or basement location.

3. A warm dry location is a must. The temperature should be reasonably uniform, and must never fall below 50°F. A dependable source of heat must be available for heating the chlorinator enclosure during cold weather.

4. The chlorine cylinder must not be placed near a source of heat or in direct sunshine. The cylinder must be kept as cool or cooler than the chlorinator.

MAINTENANCE AND REPAIRS

Neglect is fatal to a chlorinator. The equipment depreciates rapidly once deterioration sets in, unless repairs are made promptly. Certain points to observe in maintenance are:

1. Set up a regular inspection schedule.

2. Any odor of chlorine, or green discoloration of metal parts is a sure sign of a chlorine leak. STOP ALL LEAKS AT ONCE! Locate the leaks by the use of ammonia solution ("stronger" ammonia water at drug store). Moisten a rag with the ammonia solution and rub the joints and connections. Chlorine will combine with the ammonia to form a white "smoke".

3. Use a new gasket each time a joint is disconnected. Don't economize on gaskets.

4. Never leave an open connection on the gas side of the machine. Moisture will enter and may badly damage the equipment.

5. Never use water or oil in cleaning chlorinator parts. Use carbon tetrachloride or wood alcohol.

6. Treat the equipment with respect. Use the proper wrenches and avoid force in connecting or disconnecting a joint. Use the wrenches provided with the machine. Do not use a stillson wrench. Use the hands only on threaded hard rubber parts.

7. Use a Dixon Graphite No. 692 on the threads of all hard rubber parts.

SPARE PARTS

Where continuous operation is required, duplicate equipment must be provided. In small plants where operation can be suspended to make repairs, a good stock of spare parts will suffice. The following parts and materials should be on hand.

Instruction book.
Special wrenches furnished with the machine.
Gaskets - a complete set. Be sure and replace as used.
Asbestos cord packing for auxiliary tank valve.
Replacement for all glass parts.
Bottle of ammonia solution.
Extra auxiliary tank valve.
Extra flexible tank line.
Test kit for residual chlorine and a supply of orthotolidine testing solution.
Chlorine gas mask.
Address and telephone number of nearest chlorinator service man.
List of nearby plants having similar equipment and parts.

If repairs cannot be made locally and help is needed, call the State Health Department. The State Health Department can locate repair parts for most styles of equipment during an emergency.

HOW TO COMPUTE THE AMOUNT OF CHLORINE USED

The chlorine cylinder must be kept on platform scales to enable the operator to maintain an accurate check on the rate of feed, and the amount of chlorine remaining in the cylinder. THE CYLINDER PRESSURE DOES NOT TELL HOW MUCH CHLORINE IS IN THE CYLINDER. The cylinder pressure will go up and down with the temperature, but will remain high until the cylinder is almost empty.

Chlorine doses are computed in parts per million. One part (one unit by weight) of chlorine in one million parts (one million units by weight) of water is one part per million. For example: One pound of chlorine in one million pounds (121,000 gallons) of water is one part per million.

REMEMBER: 8-1/3 POUNDS OF CHLORINE IN ONE MILLION GALLONS OF WATER IS ONE PART PER MILLION.

Sample Calculation - Three pounds of chlorine has been used in treating 650,000 gallons of water. What is the dosage: Dosage in parts per million = $\frac{3}{650,000} \times \frac{1,000,000}{8.3}$ = 0.55 ppm.

Each chlorinator is equipped with a measuring device (orifice tube, bubbling meter, pulsating tube, rotameter, etc.) which will tell the operator how much chlorine is being applied. Orifice tubes are rated in pounds per 24 hours, and volumetric bubbling and pulsating meters deliver a definite volume of chlorine with each bubble or pulsation which can be converted into pounds per 24 hours by timing the rate and referring to a chart. (See Fig. 7).

HYPOCHLORINATORS

Two types of hypochlorite feeding machines are in use. One type is basically a diaphram pump similar to the automobile fuel pump. A diaphram is moved back and forth is a closed chamber. On the back stroke hypochlorite solution is drawn into the chamber; on the forward stroke the solution is

expelled from the chamber into the water supply to be treated. The rate of feed is adjusted by changing the length of stroke or the reciprocating speed or both. The equipment is powered by a fractional horsepower motor, or in some cases by water power. The Wallace and Tiernan Hypochlorinator, the Proportioneer Chlorofeeder and the Lapp (Wilson) Pulsafeeder are basically this type.

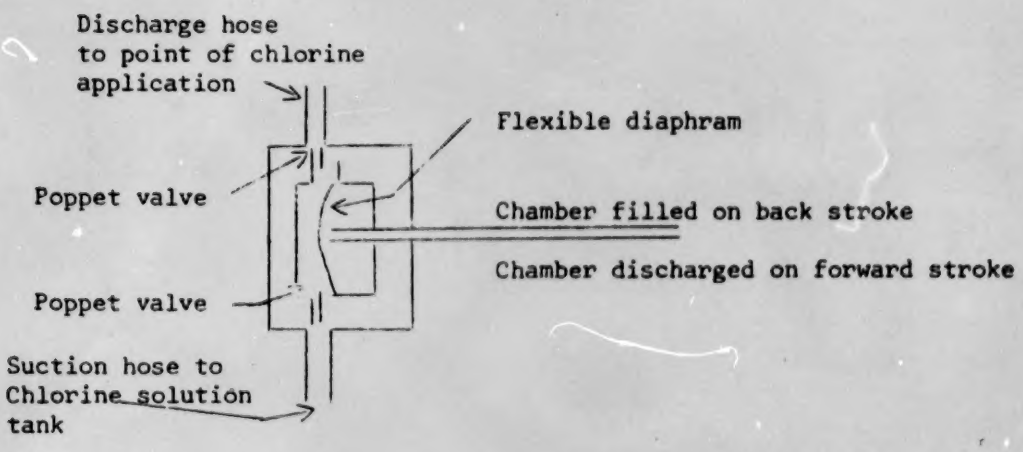


Fig. 5 - Sketch - Basic Principle of
Displacement Type Chemical Pump

Another type of hypochlorinator may be used when the solution is not applied under pressure, but is dropped by gravity into an open tank, basin or non-pressure pipe. This type of feeder consists of a solution tank, a draw off pipe and a mechanical device for lowering the draw off pipe at a controlled rate. The American Water Softener Company, the Omega, and the Permutit solution feeders are of this type.

Trouble free operation of a hypochlorite feeder depends to a considerable degree upon careful and proper preparations of the hypochlorite solution. If the solution is prepared from a powder it is better not to dump the powder in the solution tank. Instead make up a stock solution in a separate tank and after allowing for settling, transfer the clear solution to the hypochlorinator feed tank. Discard the sludge.

CHLORINTION
APPENDIX
BUFF

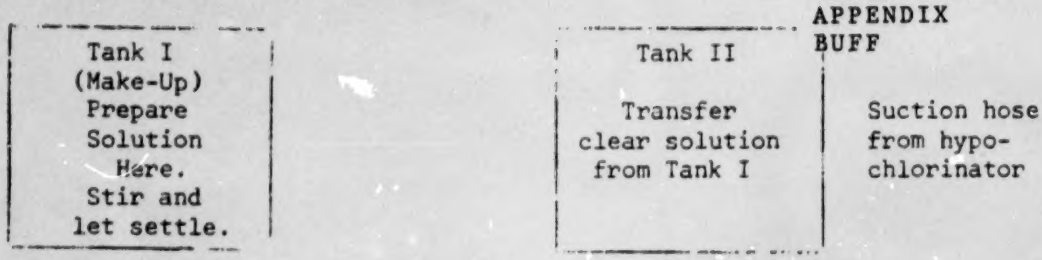


FIG. 6 - PREPARE CHLORINE SOLUTION IN SEPARATE TANK

If a liquid (sodium) hypochlorite is to be used, then it may be applied directly into the hypochlorinator feed tank.

FEEDING HYPOCHLORITE IN AN EMERGENCY

An operator may be called upon to feed hypochlorite in an emergency, and have to use a homemade feeder. This may be done in several ways as follows:

Batch Dosing - In some cases it may be necessary to sterilize a tank, basin, or reservoir of water. If the water is clear and unlikely to have a heavy chlorine demand, try a dose of one part per million. Compute how much water the basin holds, and determine how much of the particular chlorine compound will be required by referring to Figure 7 or compute the dose as instructed on page 9. Add the chlorine as uniformly as possible to the basin, and agitate if possible. After 30 minutes make a chlorine residual test at several points in the basin. If residual chlorine is present the water has been disinfected. If no residual chlorine is present add more chlorine and test again.

Homemade Feeders - See sketches on the next page for methods of making homemade hypochlorite feeders.

HOW TO KEEP A UNIFORM SOLUTION IN THE HYPOCHLORINATOR FEED TANK

It is important when using a hypochlorinator that a hypochlorite solution of uniform chlorine strength be prepared day after day. Local conditions will determine the best strength to use, but normally do not exceed ...

The recommended method of preparing a uniform solution is as follows: Measure the depth of the solution make up tank in inches. For each inch of tank depth add a definite amount of hypochlorite powder, say one ounce, two ounces or three ounces, etc. When the operator wishes to replenish the tank all he needs to do is to measure how many inches have been used, and this will automatically tell him how many ounces of hypochlorite powder is needed before filling the tank with water.

Example: The operator is using a solution make up tank having a depth of 30 inches. He estimates or knows from experience that he will use about 10 ounces of high test hypochlorite each day, so he decides that he will use one ounce of hypochlorite powder for each inch of tank depth. When he makes up the tank for the first time he weighs out 30 ounces of powder. adds it to the tank and fills it with water. Two days later he measures the tank and finds that 18" of solution has been used. He then weighs out and adds 18 ounces of powder and fills the tank again. In this fashion he keeps the solution at constant strength.

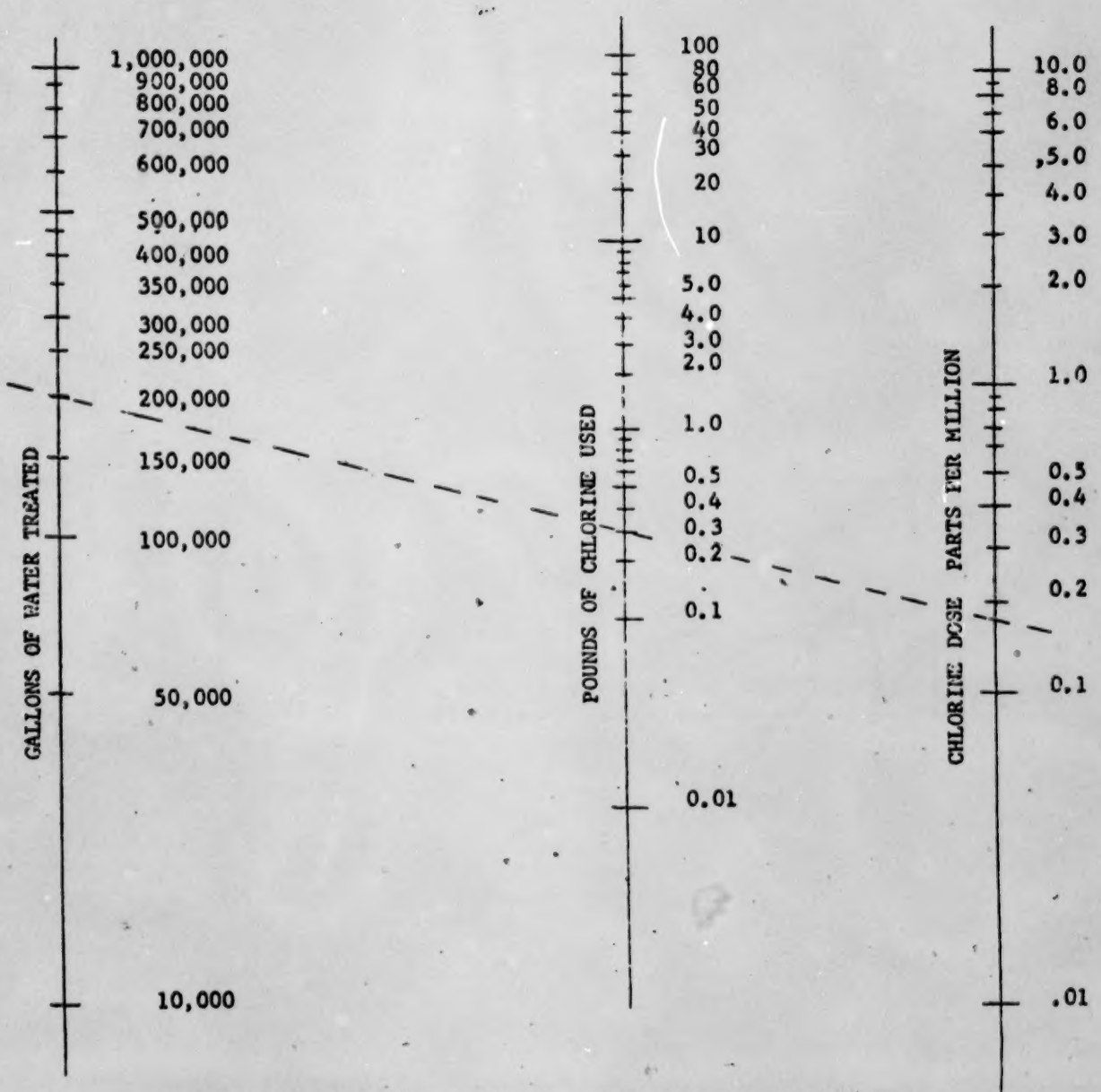
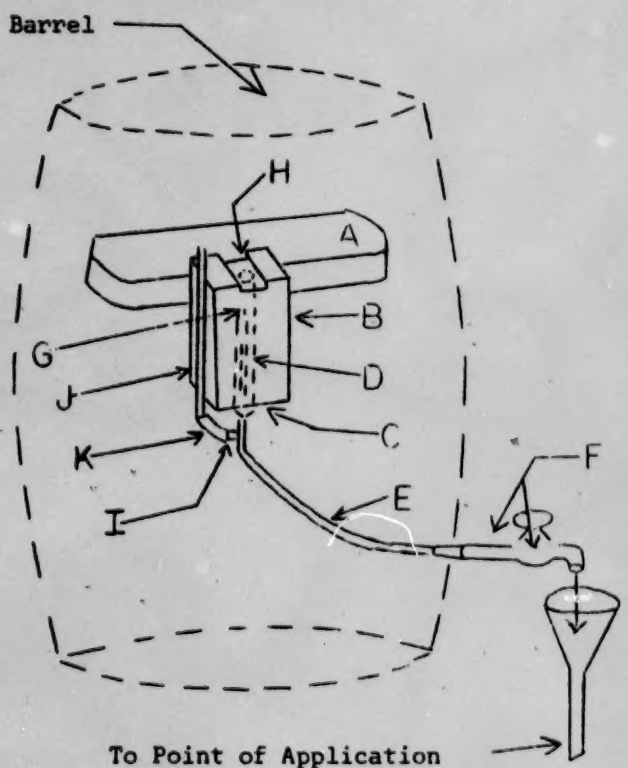


FIG. 7 - ALIGNMENT CHART FOR COMPUTING CHLORINE DOSAGE

Example shown by dotted line: - 0.3 lbs. chlorine applied to 200,000 gals. water - Dosage -- 0.18 p.p.m.



A - 2" x 12" piece of board of such a length to float freely in barrel.

B - 4" x 4" piece 6" long.

C - Rubber stopper.

D - 8" glass tube with orifice tip.

E - 1/2" rubber tubing.

F - 1/2" wood or hard rubber cock.

G - 1" bored hole.

H - Inlet to orifice.

I - Glass tee.

J - Glass vent tube.

K - Couplings made from rubber tubing.

FIG. 8 - FLOATING ORIFICE FEEDER

WHAT RECORDS SHALL BE KEPT

An accurate record of chlorinator operation shall be kept. This shall include hours of operation, amount (or rate) of water treated, amount of chlorine applied, chlorine residual, and trouble and remarks. A permanent record shall be kept locally, and a weekly report made to the State Health Department. Where chlorination is the only treatment, use the card shown below. At filtration plants include the record of chlorinator operation on the "Summary of Filter Plant Operation".

WEEKLY REPORT---CHLORINATOR OPERATION

CITY _____ COUNTY _____

WEEK ENDING SATURDAY _____ 19 ____

DATE	WATER TREATED GALLONS	CHLORINE USED LBS.	CHLORINE RESIDUAL TEST PPM	WATER CLEAR OR TURBID	TROUBLES AND REMARKS

EW-87 Operator in Charge _____

RESIDUAL IN SYSTEM

In many instances it is not practicable with a normal dose of chlorine to maintain a residual throughout the system. Most systems have dead ends with low water consumption and the residual will be used up before the water reaches the consumer.

In systems where the storage reservoir or tank floats on the line and holds a considerable quantity of water, the water feeding back into the system from the reservoir will be free of chlorine. Chlorine residual is reduced by exposure to sunlight.

116

CHLORINE RESIDUAL IN SWIMMING POOLS

The State Health Department recommends that swimming pool water be chlorinated heavily enough to maingain a residual of 0.3 ppm "Free" chlorine, or if this is not possible, a residual of 0.8 ppm "Combined" chlorine.

CHLORINATION OF SEWAGE

The addition of chlorine to sewage serves many purposes, especially disinfection, control of undesirable growths in sewage treatment plants and receiving waters; delay of decomposition in sewerage systems, sewage treatment plants and receiving streams; control of odors; increased removal of grease in aerated skimming tanks; and reduction of Biochemical Oxygen Demand.

For disinfection a contact period of 10 minutes is the minimum and a 0.5 ppm residual must be obtained. The following table shows the probable amounts and chlorinator capacities needed.

Type of Sewage or Effluent	Probable Amounts		Chlorinator Capacities	
	ppm	lb. per day per 1,000 persons	ppm	lb. per day per 1,000 persons*
Raw Sewage (depending on strength and staleness).	5 to 25	3 to 17	30	20
Settled sewage	3 to 18	2 to 12	20	15
Chemically precipitated sewage . .	4 to 12	3 to 8	17.5	12.5
Trickling-filter effluent	3 to 6	2 to 4	15	10
Activated-sludge plant effluent . .	2 to 4	1 to 3	10	7.5
Intermittent sand-filter effluent	1 to 3	1 to 2	8	5

*For sewage flow of 80 g.p.d. per capita.

CHLORINOUS TASTES

If the application of chlorine is carefully controlled, it is possible to disinfect a water supply without creating a chlorine taste or odor. The average person cannot detect a chlorine residual of 0.2 parts per million. With some waters it may be possible to carry a much higher residual without causing an objectionable taste.

If chlorine is applied to a water containing a very small amount of phenol compound, the resulting chloro-phenol taste will be strongly medicinal. The public will usually blame the taste on over-chlorination, whereas the trouble arises from the combination of chlorine and phenol.

OPERATORS LICENSE REQUIRED

Under a regulation adopted by the State Board of Health (as authorized by Law) the person in responsible charge of a water plant where disinfection is practiced must secure a water plant operators license from the State Health Department. A third class license is acceptable for the smaller plants. Detailed information regarding the examination may be obtained from the Division of Sanitary Engineering, State Health Department, Charleston, West Virginia 25305.

QUESTIONS FOR STUDY AND REVIEW

1. What is chlorine?

2. In what form does chlorine exist in the steel cylinders delivered to the water plant?

3. What happens to the pressure in a chlorine cylinder when the temperature increases?

4. What may happen if a cylinder of chlorine is exposed to fire or other intense heat?

5. What first aid should be administered to a person overcome with chlorine gas?

6. What is chloride of lime? High strength calcium hypochlorite? Sodium hypochlorite?

7. What is residual chlorine?

8. Approximately how much chlorine is needed to sterilize a normal water supply?

9. What is meant by chlorine contact period?

10. What is usually an acceptable chlorine residual and contact period?

11. Give the procedure for making the orthotolidine test for residual chlorine?

12. What is a chlorinator?

13. What is a hypochlorinator?

14. Sketch and describe the chlorinator or hypochlorinator with which you are familiar.

15. What precautions should be observed in locating and installing a chlorinator?

16. Compute the following chlorine dose: An operator applies 2 pounds of chlorine in treating 200 000 gallons of water. What is the dosage in parts per million.

17. How would you proceed to disinfect a water supply during an emergency if chlorinating equipment was not available?

18. What records of chlorination should be kept by the operator?

19. What is ammonia-chlorine treatment?

20. What effect does sunlight have on chlorine residual?

(Excerpts from article appearing in Journal of American Water Works Association, Volume 30, Number 10)

Case 1. Cylinder Accident. Wall of cylinder in service failed. Operators were not provided with gas masks. Nearby industrial company sent men with all-service gas masks. Persons attempting to use them were all gassed - none severely. The all-service gas masks were later found to be in poor condition.

Prevention Comment. 1. Cylinder has passed required five year inspection for strength. Internal examination would have revealed defects not registered during required pressure test. 2. A poor gas mask is worse than no gas mask.

Case 2. Cylinder Accident. Customer didn't want to buy a chlorinator. He attempted to chlorinate his supply by discharging gaseous chlorine from a 100-pound cylinder through a rubber tube into an open barrel through which cold water was continuously running to the plant discharge line. An official reporting trouble, said in part"... we tried to open the (cylinder) valve a trifle and opened it too much. We (later) tried to close the valve and found it frozen. We filled the reservoir with gas and almost killed a man or two. We finally managed to unscrew the hose and put a cap on the valve outlet." Subsequent investigation indicated that no one was seriously injured.

Prevention Comment. None needed.

Case 3. Two cylinders taken from storage, alleged to be leaking were thrown into the intake pond. The warm water (August) did not absorb the chlorine and the valves were rapidly disintegrated under water. Chlorine gashed up into the air and damaged 61 trees adjacent to the pond. No personal injuries.

Prevention Comment. Cylinder should never be submerged in ponds or other bodies of water if the water is warmer than 49.2°F. The chlorine leak will become worse very rapidly and the cylinder will quickly get out of control and do much damage to the adjacent premises. A sure way in all cases is to blow the chlorine into a lime slurry or caustic soda soltuion. 1.25 lb. caustic soda or lime will be needed for each pound of chlorine to be absorbed.

Case 4. When operator attempted to change cylinders he was gassed because the valve on the cylinder being disconnected was not closed, but "frozen" open. The operator spent one day in the hospital recuperating from his negligence. Complete recovery was made.

Prevention Comment. It is obvious that one must be certain that cylinder valves are tightly closed before disconnecting them.

CHLORINATORS*

(LOCATION - OPERATION - MAINTENANCE)

It is with regret that this paper must be prefaced with the statement that there is no magic formula for making a chlorinator take care of itself. It is hoped, however, that by recording and adhering to certain fundamental rules and principles, operators will be able to minimize their maintenance and operation problems.

Location of Chlorinator

Obviously, the first step in proper maintenance of a chlorinator is proper installation---and the first step in proper installation is location of the equipment. If possible, the location of the chlorinator should be near the point of application so as to minimize the length of solution lines, and it also should be as convenient as possible to the operators so that frequent inspections will be encouraged.

It is fundamental that ease of handling chlorine containers should be considered in selecting a site. The size of the containers to be handled has considerable bearing on this, but in general this discussion is confined to 100 and 150-pound net weight cylinders. The handling of ton cylinders magnifies the problem considerably and is beyond the scope of this paper.

It might properly be said at this point that chlorine cylinders should not be located in basements or generally below grade level because of ventilating difficulties, chlorine being about 2½ times heavier than air. Rules for handling chlorine are covered later herein.

Equipment Housing

Proper construction and equipping of the chlorinator building can eliminate a number of maintenance problems. There should be ample room for the equipment to be installed so that sufficient space remains around the chlorinator for easy inspection, operation and servicing as required. There should be plenty of light for this purpose. It is surprising how many chlorinators have to be worked on with flashlights and, in some cases, practically standing on one's head.

*Source: Water Works Operators Manual, Third Edition, 1972, Chapter XVIII**; Alabama Department of Public Health Bureau of Environmental Health, Montgomery, Alabama.
**Adapted from a lecture given by James W. Fly, Wallace and Tiernan Representative.

Heating is of prime importance. In the winter, efforts should be made to keep the temperature between 65° and 70°F. Low temperature not only affects operation of the chlorinating equipment, but it discourages proper maintenance from a personal comfort standpoint.

The chlorinator room should be properly ventilated. In certain circumstances natural ventilation will be sufficient. Where large quantities of chlorine are being stored and used and where natural ventilation is a problem or a hazard, forced ventilation should be provided. A chlorinator building located in the open should always contain windows for ventilation as well as lighting, and in addition there should be openings at a low point and a high point in the room for continuous ventilation. In remotely located buildings, it is generally necessary to cover windows with substantial shutters to protect them from boys with rocks and air rifles.

The chlorinator room should be as dry as possible. Heat and ventilation have a large part in this, but proper drainage is also a contributing factor. Maintenance of water piping cannot be overlooked.

All of these things---ample room, proper heating and ventilation, and adequate light---are conducive to cleanliness. A clean piece of equipment is usually in good condition mechanically. A plant's chlorinator installation is valuable and should be protected.

General Conditions for Maintenance

If a plant is fortunate enough to have duplicate chlorinators, the maintenance problem is eased considerably by reason of not having to wait until a little problem gets big and in not having to do a hasty job of repair. Whether or not duplicate chlorinators are provided, it is assumed that the good operator will become as familiar as possible with the equipment. A study of the equipment should begin when it is installed and when there is a representative of the manufacturer present. This study can continue, if necessary, with subsequent visits of the manufacturer's representative. Instruction books furnished with the equipment contain a great deal of both general and specific information; but in spite of this, problems sometimes arise that are not in the book.

With proper knowledge of the equipment, regular and adequate inspection is a "stitch in time". At these regular inspections, it should be determined that the equipment is performing its functional duty; that is, it is feeding the desired amount of chlorine and there is no evidence of trouble to come. The latter condition may be determined by liquid levels, gauge readings, or in other ways peculiar to the particular unit.

Because of the presence in all commercial chlorine of the impurity, ferric chloride, it will be necessary to clean certain of the internal working parts of the chlorinator from time to time. The use of a chlorine inlet block heater to heat the gas, as received at the chlorinator, will minimize but not entirely do away with the need to clean these parts of the machine periodically. The impurity referred to is the reaction product of the chlorine on its steel container. It is not only water soluble, it is also hygroscopic or moisture attracting. Its water solubility makes cleaning of rotameter, chlorine pressure reducing valve, springs, and other internal parts with water very easy; but its hygroscopic nature makes trouble inside the machine if much moist air is drawn in through open lines when the operator changes chlorine tanks. For this reason, injection water should be turned off and tank connections changed quickly to prevent or minimize indrawing of air at such times. The use of an auxiliary tank valve at the cylinder permits keeping the chlorine inlet closed at these times and is strongly recommended.

A further word is indicated on the cleaning of internal parts with water. It is absolutely essential to follow such water cleaning either with heat or solvent drying so that the dry-gas parts of the machine will be completely moisture-free when reassembled. Wood alcohol is good for this purpose; or if denatured grain alcohol is used, it, in turn, should be followed by methyl chloroform (not to be confused with ordinary chloroform---be sure your supplier notes the difference). A few years ago it was common practice to flush the denatured alcohol with carbon tetrachloride to leave only traces of this (inert-to-chlorine) solvent if not absolutely dry. However, the very great breathing hazard to the user of "carbon tet" has become inescapably evident with many reported deaths from irreversible liver damage due to breathing even small quantities of it over long periods of time. For this reason, the use of carbon tetrachloride is no longer recommended for this purpose.

Moist chlorine is particularly destructive. Materials which are not affected by dry molecular Cl_2 gas, such as black wrought-iron pipe, copper tubing, brass fittings, etc. will not withstand the attack of moist chlorine, which is a mixture of hypochlorous and hydrochloric acid ($Cl_2 + HOH \longrightarrow HOCl + HCl$). This is the reason that careful inspection of a chlorinator and all chlorine lines is so important. The dry, non-aggressive Cl_2 gas, when it escapes into moist air, becomes viciously corrosive to most ordinary equipment designed to do other jobs but not especially to resist moist chlorine. Electrical gear with wires of copper and contacts of copper-bearing alloys are especially susceptible to damage.

To protect external parts of the chlorinator itself, it has long been a practice to apply grease. The object of this, of course, is to insulate the metal from moisture, particularly moisture that has picked up chlorine. Daubing of grease all over the chlorinator seems to be just the lesser of two evils,

One of the more important details of an inspection is to check for leaks. Any leak is highly important and should be corrected at once. No leak is small enough---repeat, no chlorine leak is small enough to warrant putting off its immediate correction. We all procrastinate, but we must not do so around a chlorine leak. In general, dry green corrosion indicates a leak at some point other than at the spot; however, if the green spot is slick and wet, you have probably found the escape point, and steps can then be taken to stop the escape of the chlorine gas. The most effective way to locate leaks in addition to searching for a wet corroded spot is to use an ammonia saturated cloth on a stick or wire. It may not be possible to get within a foot of a leak by "sniffing" around, but a touch of ammonia water to the suspected joint or tube assembly will quickly spot the escape of chlorine with the telltale white ammonium chloride fumes. A supply of ammonia water should always be kept on hand near the chlorinator. It is surprising, however, how many chlorinator installations do not have a bottle of ammonia available; or where there is a bottle of ammonia, it has lost all of its strength due to being left open. Some operators may take this regular inspection schedule lightly, but there are others who will not make this mistake. Among those operators who seriously and carefully inspect their equipment are those who have learned their lesson the hard way. It is easy to experience a false sense of security when observations over a long period do not disclose any difficulty, but the operator is urged to continue to inspect carefully and regularly. The need for such inspection also applies to models of chlorinators which are themselves relatively corrosion resistant, but located near other equipment such as motors, control panels, starter switches and so forth, because an undetected leak can do a tremendous amount of damage overnight. Prompt correction of any leak found on an inspection can head off such trouble.

Operating Suggestions

When it comes to actually working on a chlorinator, certain equipment should be available and certain rules should be followed. In the first place, there should be a supply of spare parts and gaskets. The spare parts should certainly include glassware.

Working on a chlorinator generally involves disconnecting gaskets to joints. The old gaskets, particularly if of fiber lead, should almost invariably be discarded. Occasionally a soft rubber gasket that has been in use only a short time may be used again if necessary. After the old gasket has been removed, the gasket joint should be cleaned. Normally, it is necessary to use only one gasket at a joint. Frequently, two or more gaskets are found at one joint, which is poor practice and one which certainly increases the possibility of leaks.

as there seems to be natural aversion to doing the necessary work on a chlorinator that is covered with grease. If grease is to be used, it is better to rub a light vaseline on lightly with rag and remove the excess with a clean rag. This procedure maintains the good appearance and returns to the premise of clean equipment normally being in good mechanical condition. Another practice which has given good results in maintaining the appearance of chlorinators is the application of a good paste-type floor wax, applied to the finish of the machine in one or two thin layers much as one would Simonize an automobile. Excellent results in chlorinator maintenance are obtained in some water plants where the finishing up of a cylinder of chlorine gas, signalling for a change of cylinders, is at one and the same time a signal for a complete chlorinator inspection and a wax and polish job. It is admitted that this particular system would not be practical for high capacity water plants which have to change cylinders every day or so, but it is strongly recommended to the smaller plant operators whose cylinders last anywhere from one week up.

For the protection of the plated parts of a chlorinator, an excellent protective coating is found in clear lacquer. It is probably a lot less trouble in the long run than greasing and, if anything, is more effective for the purpose. Of course, for joints that are disconnected often, such an auxiliary tank valves, maintaining a continuously lacquered coating could be somewhat a chore. Recently, there has appeared on the market clear plastic lacquer in pressure spray cans. An effective job of reaching inaccessible places and of doing a complete lacquer job with ease can be accomplished by this method.

Lubricants for hard rubber and metal threads should be used with caution. No lubricants should be allowed to remain where chlorine is normally present. This brings up a note of caution regarding iron pipe headers for chlorine gas. Pipe fitters frequently use oil in threading the pipes; therefore, the inside of the pipes should be swabbed clean before assembling. Be sure there is no moisture left in the pipes after assembling.

It should be re-emphasized that a supply of strong ammonia should be on hand, with the bottle kept stoppered and preferably in a cool place. It is not advisable to let ammonia get too hot. Pressure builds up in the bottle; and if it doesn't blow out the stopper, it may blow out in someone's face when the stopper is removed. This has happened and can be serious. Some operators who know this, keep their ammonia in the tray water of their water diaphragm chlorinators. This is not without an element of danger since breaking the ammonia bottle in the tray may possibly result in a violent reaction of the ammonia with the chlorine content of the tray water. Concentrated ammonia water and concentrated chlorine water react explosively in some cases. When purchasing a new bottle

of ammonia for leak testing, be sure to ask for the non-sudsing household ammonia in a grocery store or strong aqua-ammonia at the drugstore. It is almost always necessary at the drugstore to point out specifically that you do not want aromatic spirits of ammonia, as this is of little value in leak testing.

Handling Chlorine

Certain things should be known about chlorine by those who are to handle it. The most common sizes of containers in use are 100, 150 and 2,000-pound cylinders. The content of these cylinders is liquified chlorine gas. Fortunately, the gas liquifies at comparatively low pressures, which simplifies handling large quantities of the gas in condensed form. In hot weather the pressure on the inside wall of a cylinder may be as high as 125 pounds per square inch or more. Pressure on a new cylinder is sometimes higher than normal due to the pressure of inert gases, which are soon drawn off with the first chlorine used. In cold weather the pressure in a container may go as low as 40 or 50 pounds per square inch. The temperature pressure curve contained in all chlorinator instruction books is useful for interpreting this relationship between temperatures and pressures.

The pressure in the chlorine container keeps the chlorine in liquid form. As received from the chlorine supplier, containers are a little more than three-fourths full of liquid. This is to allow for expansion of the liquid with higher temperatures. When the container valve is open, the pressure is relieved and some of the liquid passes into the gaseous form. It is in this form that it is controlled and measured in the chlorinator.

The change from a liquid to a gas requires heat, which is obtained from the surrounding air. The absorption of heat has a cooling effect on the cylinder, thereby reducing the pressure. Therefore, if gas is drawn off too rapidly, freezing may occur which, in turn, will retard the flow of gas. It can be seen that proper circulation of air around the cylinders is important so that the cooled air can be replaced by warmer air.

The maximum rate of withdrawal from a 100 or 150-pound cylinder at normal room temperature is about 40 pounds per day, although this rate may be doubled for short periods. If more than 40 pounds per day are required, a number of cylinders may be hooked up to a common manifold. A note of caution is in order here. If hot cylinders under high pressure are connected by a manifold with cooler cylinders under lower pressure, gas may pass from the high pressure to the lower pressure cylinders and reliquify there. This could be serious if the low pressure cylinders cannot accommodate the additional liquid.

A fairly common occurrence is the reliquifying of chlorine when passing from a high temperature to a low temperature area. This may occur when a newly connected cylinder has been stored in some place warmer than the chlorinator room, or it may occur when cylinders in use are placed near a source of heat, such as a radiator or other heating units. The control apparatus should always be nearer to the source of heat than the container. In many cases, containers are placed in separate rooms, which are cooler than the chlorinator room, and this chlorine piped to the subsequent chlorinator. Installation of a chlorine pressure reducing valve near the cylinders and transmission of the gas under reduced pressures (25-30 psi) reduces the likelihood of reliquefaction. The importance of preventing reliquefaction cannot be overemphasized, for almost all post World War II chlorinator designs make use of PVC and other plastics which, though fine for chlorine solution and chlorine gas under vacuum, are not usable for chlorine gas under pressure or liquified chlorine.

All chlorine containers have a fusible plug designed to melt at about 160°F. to relieve dangerous hydrostatic pressure resulting from high temperatures. These plugs certainly never should be tampered with, and the temperature of the chlorine room should never be higher than necessary for good operation. Artificial heating of containers or piping to increase the gasing rate can be extremely dangerous. If the chlorine withdrawal must be increased to rates in excess of 40 pounds per day per 150-pound cylinder or 500 pounds per day per ton container for more than 30 minutes at a time, a commercial chlorine evaporator should be purchased for this purpose.

When high rates of chlorine usage are engineered and planned for, chlorine is handled as a liquid from the container to the chlorinator location. It is then absolutely necessary to evaporate the chlorine in an evaporator at the chlorinator end of the line so that only gas phase is passed to the chlorinator to be metered, put into solution and applied. This method of handling is used principally in high capacity water and sewage installations and the operating personnel of these installations must be trained in the established procedures to follow for safe operation.

The following simple set of rules has been devised for handling all chlorine containers:

1. A container holding chlorine should be handled with care.
2. The valve bonnet should not have to support the full weight of the container such as in hoisting and lifting.
3. Do not drop containers or permit them to strike each other violently.
4. Be sure that the container valve is closed before removing the valve protecting cap.
5. When returning empty containers, close the valve and test for leaks. Be sure that the valve protective cap and the bonnet are in place. The cap should be kept with the container during use. It is illegal to ship a defective or leaky container.

6. Open the container valve slowly. Use only wrenches supplied by the manufacturer. Cylinder valve wrenches are 3½ inches long, and they are that length for a reason.

7. The thread on the outlet of a cylinder valve is not a standard pipe thread. Do not try to use a standard pipe thread fitting on it. This is a 3/4-inch straight thread or union thread.

8. Store containers where it is dry and preferably cool. Do not store where there is any fire hazard.

9. Weighing is the only means of determining how much chlorine is in a cylinder. Scales having a platform flush with the floor are preferable.

10. Operate chlorine valves once a day to keep the stem polished and free. Opening either tank valves, auxiliary tank valves or header valves about 3/4 of a turn to one full turn is, in almost all cases, sufficient for normal use. Opening the valve more than this increases chances of the packing loosening enough to leak.

QUESTIONS

1. Chlorine gas is approximately two times lighter than air.
   (T) (F)
2. Chlorine leaks tend to seal themselves if not disturbed.
   (T) (F)
3. When a chlorine leak is found with ammonia, a black fog forms.
   (T) (F)
4. If exhaust ducts and air inlet ducts are installed in chlorinator rooms, they should be at ceiling level.
   (T) (F)
5. If your chlorinator fails completely or you run out of chlorine, and you know that the source of supply is contaminated, what would you do?
6. The fusible safety plugs in chlorine cylinders are designed to melt at 212°F. to prevent exposion of the cylinders.
   (T) (F)
7. The amount of chlorine in a cylinder can be figured from the pressure on the cylinder's pressure gauge.
   (T) (F)
8. Direct heat should never be applied to chlorine cylinders.
   (T) (F)
9. Gas-type chlorinators are calibrated in:
   (a) Gallons of chlorine per hour
   (b) Gallons of chlorine per day
   (c) Pounds of chlorine per day
   (d) Pounds of chlorine per hour
   (e) Parts per million of chlorine

10. Check the appropriate blocks [X] below as to correct recommended maximum rates of chlorine withdrawal:

(a) 100 lb. cylinders

- [ ] 25 lbs/24 hrs.
- [ ] 40 lbs/24 hrs.
- [ ] 60 lbs/24 hrs.

(b) 150 lb. cylinders

- [ ] 20 lbs/24 hrs.
- [ ] 40 lbs/24 hrs.
- [ ] 65 lbs/24 hrs.

(c) Ton containers

- [ ] 300 lbs/24 hrs.
- [ ] 500 lbs/24 hrs.
- [ ] 600 lbs/24 hrs.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Published by

WEST VIRGINIA STATE HEALTH DEPARTMENT
Environmental Health Services
Drinking Water Program
1800 Washington Street, East
Charleston, West Virginia 25305
Telephone: (304) 348-2981
April, 1978

The following laboratory equipment and supplies are required of small water treatment plants for determining the physical-chemical parameters of chlorine residual (free and total), turbidity, pH, alkalinity, free carbon dioxide, hardness, fluoride ion, and performing the "jar test" for proper coagulant dosage.

Vendors not noted below, but capable of supplying equipment equal to that which is listed are acceptable. However, the Environmental Health Services Laboratory (telephone 348-0197) should be consulted before purchasing agreements are made with these vendors to confirm that equivalent equipment is being offered.

Item Number	Quantity	Items
1	1	Copy of latest edition of "Standard Methods for the Examination of Water and Waste Water", American Public Health Association, Inc., 1015 Eighteenth Street, N.W., Washington, D. C. 20036
2	1	Balance, Harvard Trip Scale, single beam, Ohaus #1450
3	1 set	Technical weights, metric, class C, 1 gm to 1000 gms
4	1	pH meter - accuracy ± 0.05 unit, scale readability ± 0.1 pH unit. Instruments meeting specifications of the Corning model 7, the Orion model 601, Beckman Zeromatic, Fisher Accumet, or equivalent are satisfactory. Laboratories purchasing a new pH meter are strongly advised to purchase one capable of functioning with specific ion electrodes.
5	3	Burettes, Automatic, with stopcock, for dispensing sulfuric acid and hardness reagent, also N/44 sodium hydroxide, 50 ml. capacity, 1/10 ml. subdivisions, complete with rubber bulb and reservoir.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
6	1	Burette Support, with large white porcelain base and a 3 way castaloy burette holder for assembling and steadying automatic burettes with reagent reservoirs.
7	1	Therometer, - 10° to 110° C.
8	4	Casseroles, porcelain (Coors #180), 210 ml.
9	6	Stirring rods, glass, 3mm diameter
10	6	Pipettes, water analysis, 10 ml. capacity
11	2	Cylinders, graduate, 100 ml. capacity, 1.0 ml. subdivisions
12	3	Flasks, Erlenmeyer, wide mouth, 250 ml.
13	6	Beakers, Griffin, "Pyrex", 1000 ml. (for jar test)
14	6	Bottles, dropping T. K., 60 ml.
15	1	DPD Chlorine residual colorimetric test kit. LaMotte, Hach, Taylor or equivalent are satisfactory kits. Kits must include free and total residual capabilities.
16	1	Turbidimeter (Nephelometric only) - Hach Turbidimeter 2100 A, Sargent-Welch, Turner Designs, Monitek, or equivalent. TURBIDITY ANALYSIS IS REQUIRED ONLY FOR THOSE SUPPLIES TREATING SURFACE SOURCE WATERS. Calibration of sealed liquid turbidity standards sealed liquid turbidity standards purchased from the instrument manufacturer must be checked frequently for settled and floating particles in order to monitor their eventual deterioration. These standards should be replaced when any major change from the previous calibration occurs or sediment appears. Solid turbidity standards composed of plastic, glass, or other materials are not reliable and should not be used.

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
17	1	Distilling apparatus, automatic, bantam still, capacity 1.8 liters per hr., Barnstead or equivalent with 2 gallons of distilled water storage. (Preiser Scientific - Catalog #17-8360 or equal)
18	2	Propipette Bulbs
19	1	Filter photometer, AC, Hach or equivalent (Hach No. 110400, 115 V, 60 Hz) with capabilities for iron, manganese, fluoride (SPADNS) method, Nitrate (cadmium reduction), with necessary reagents.
20	1	Specific ion meter - expanded scale millivolt capability, readable and accurate to 0.1 millivolt. Instruments meeting the specifications of the Orion model 407 A, the Orion model 801 A, the Corning model 110, or equivalent are satisfactory, complete with specific ion electrodes. FLUORIDE ANALYSIS REQUIRED ONLY FOR THOSE SUPPLIES FLUORIDATING.
21	1	Automatic Batch Fluoride still, Hach or equivalent, Hach Catalog #592. NOTE: If the SPADNS colorimetric method for fluoride is used, all samples must be distilled before this determination is made. If the specific ion electrode method is used (as mentioned in item #20 above), this piece of equipment can be omitted.
22	1	Stirring apparatus for "jar test", 6 unit, with variable speed control and light reflector.
23		Chemical Supplies:
	32 oz.	Sulfuric Acid, N/50 solution
	32 oz.	Sodium Hydroxide, N/44 solution
	16 oz.	Methyl Orange indicator solution
	16 oz.	Phenolphthalein indicator solution
	8 oz.	Sodium Arsenite reagent
	16 oz.	Buffer Hardness reagent
	2 vials	Hardness indicator powder (EDTA)
	32 oz.	Hardness Reagent (titrating)
	32 oz.	SPADNS Reagent
	16 oz.	Fluoride solution, standard 1.0 ppm
	1 gal.	TISAB (for use with specific ion electrode

LABORATORY EQUIPMENT AND SUPPLY REQUIREMENTS FOR A SMALL WATER TREATMENT PLANT PROVIDING COMPLETE TREATMENT

Item Number	Quantity	Items
23 cont.		method for fluoride analysis).
	1 pint	pH Buffer 7.0
	1 pint	pH Buffer 4.0

LABORATORY FACILITIES - General Notes

1. Adequate laboratory space should be made available. As a guideline, there should be approximately 150 to 200 square feet per person, regardless of test, and approximately 15 linear feet of usable bench space including a sink with hot and cold water taps.

2. Raw and post-settling water taps should be provided in the laboratory area for quality control monitoring.

3. Sufficient electrical outlets must be provided for operating the laboratory equipment.

4. GLASSWARE - all glassware purchased for laboratory use should be composed of PYREX or KIMAX type glass. This type of glass is more resistant to damage by heat, chemicals, and abuse than is regular soft glass. All volumetric glassware should be marked CLASS A, denoting that it meets federal specifications for volumetric glassware, and need not be calibrated before use.